Bayesian Analysis of Electron Kinetic Profiles.

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* See the Appendix of F. Romanelli et al., Fusion Energy Conference 2008 (Proc. 22nd Int. FEC Geneva) IAEA

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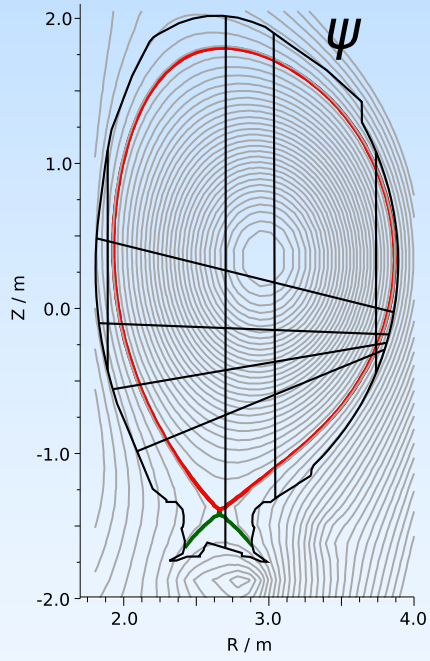
Overall Idea: Add n_e, T_e diagnostics to Bayesian Analysis

- Polarimetry
  - [Relativistic Model Testing]
- Core LIDAR
- Edge LIDAR
- Equilibrium

Interferometry + Current Tomography I

Invert interferometry data to $n_e(\psi_N)$ using weak smoothing prior based on magnetics only EFIT flux surfaces



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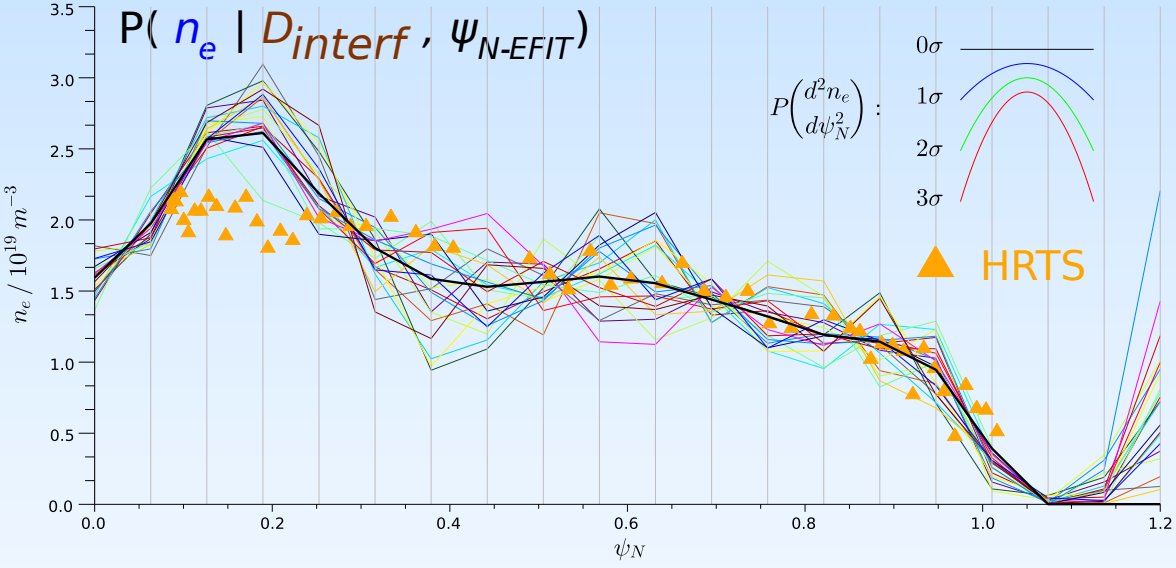
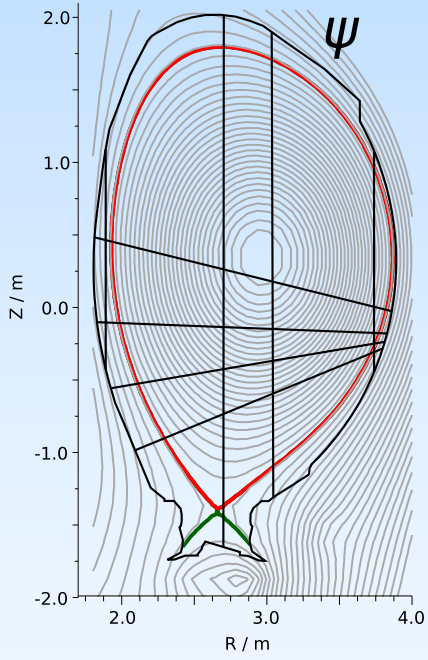


78625
Ohmic
(recovery pulse)



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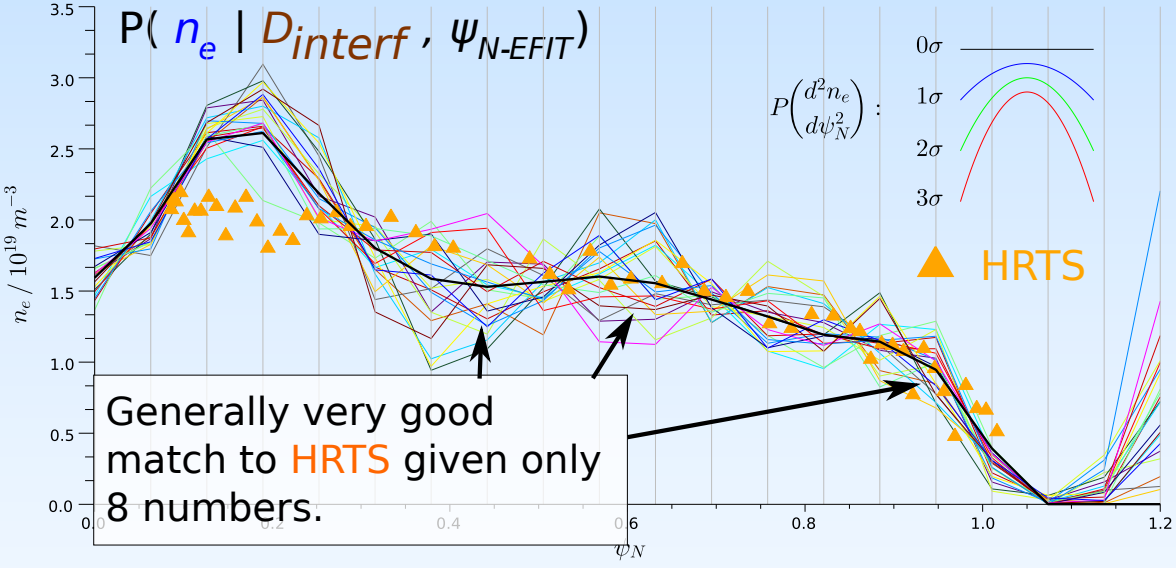

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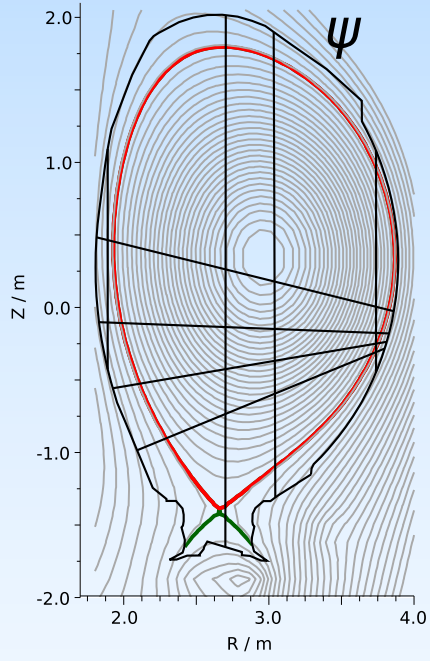

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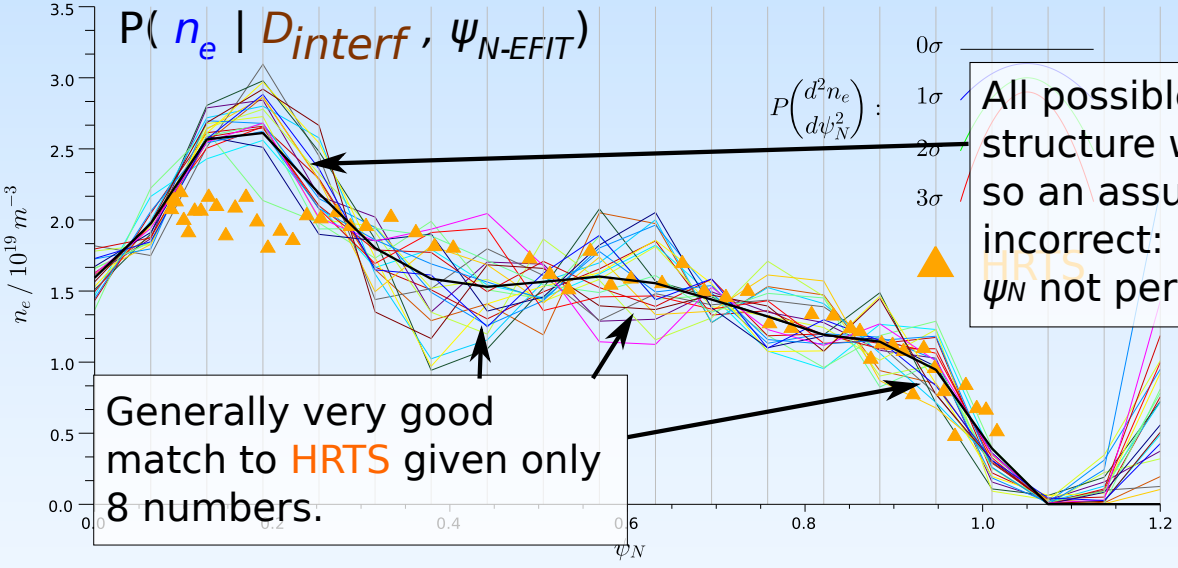

All possible profiles show structure we do not believe, so an assumption must be incorrect:
ψ_N not perfect?

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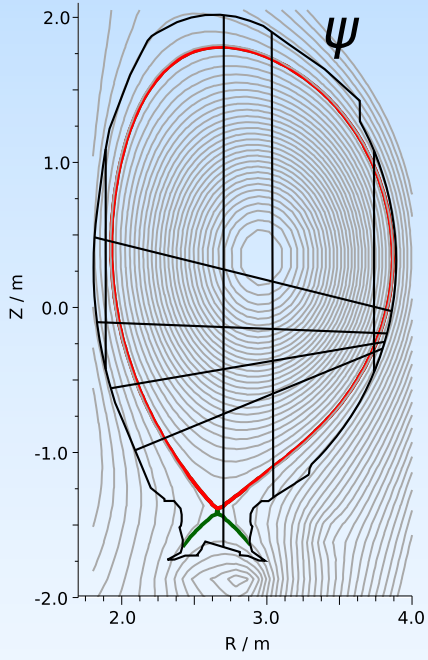

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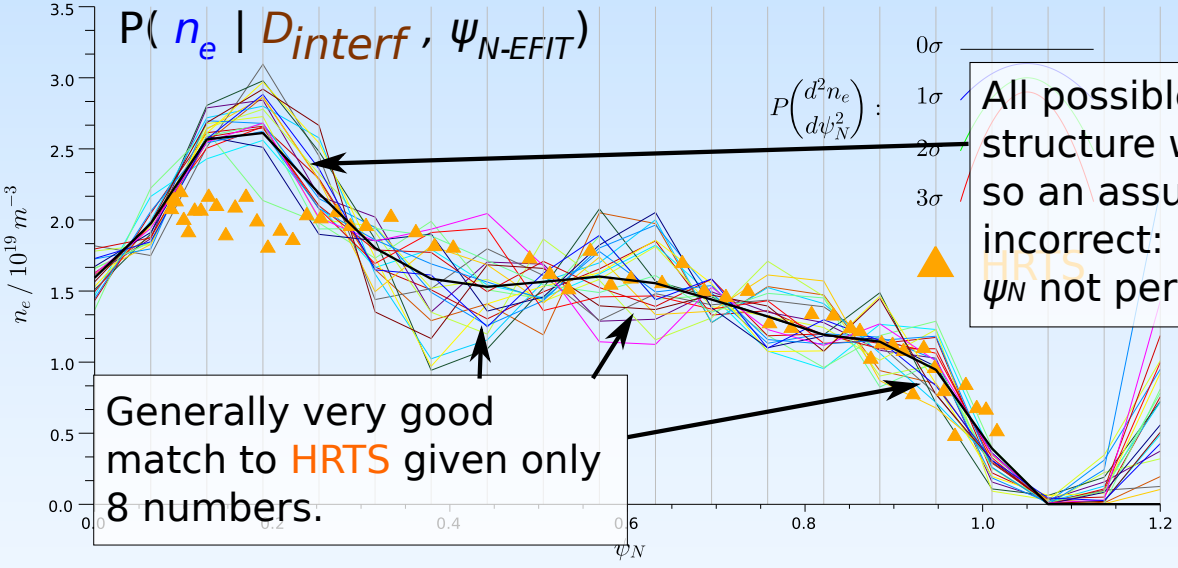

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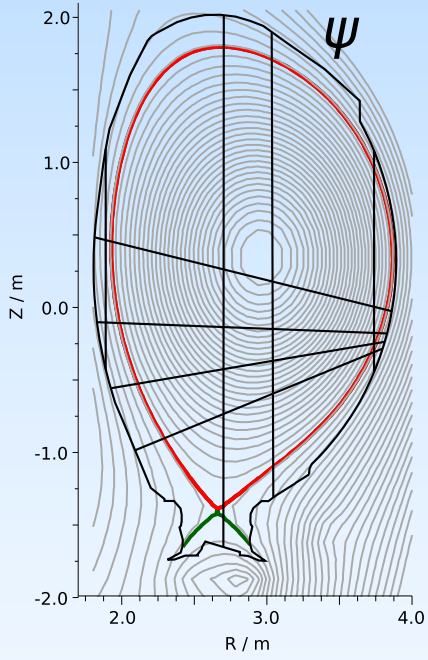

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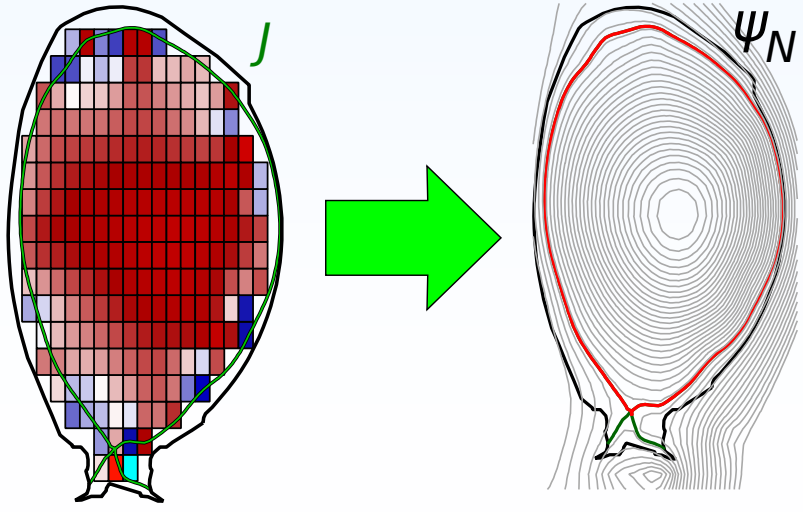
Finds combinations of J and n_e that are consistent with both interferometry and magnetics (and with n_e and J priors).



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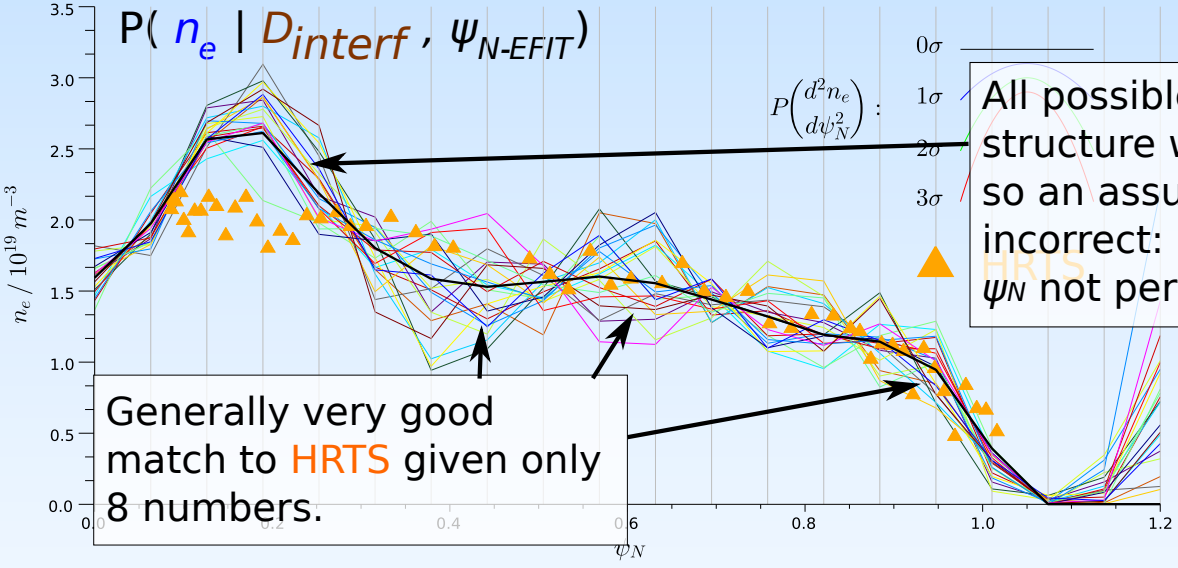

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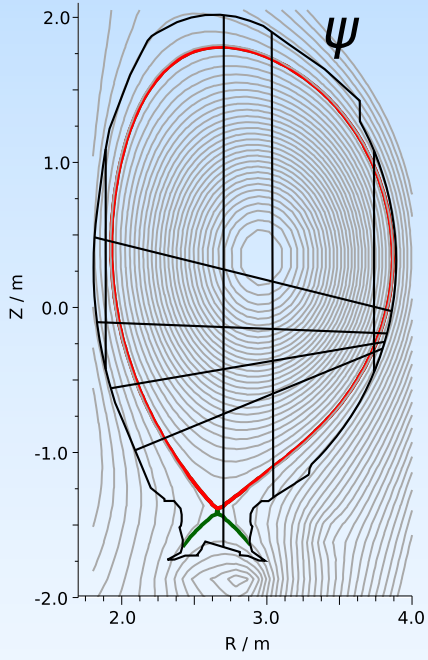

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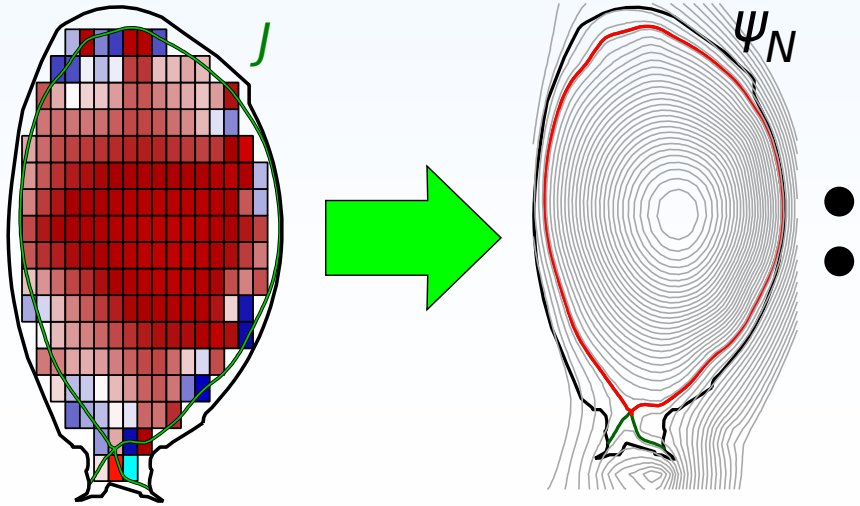

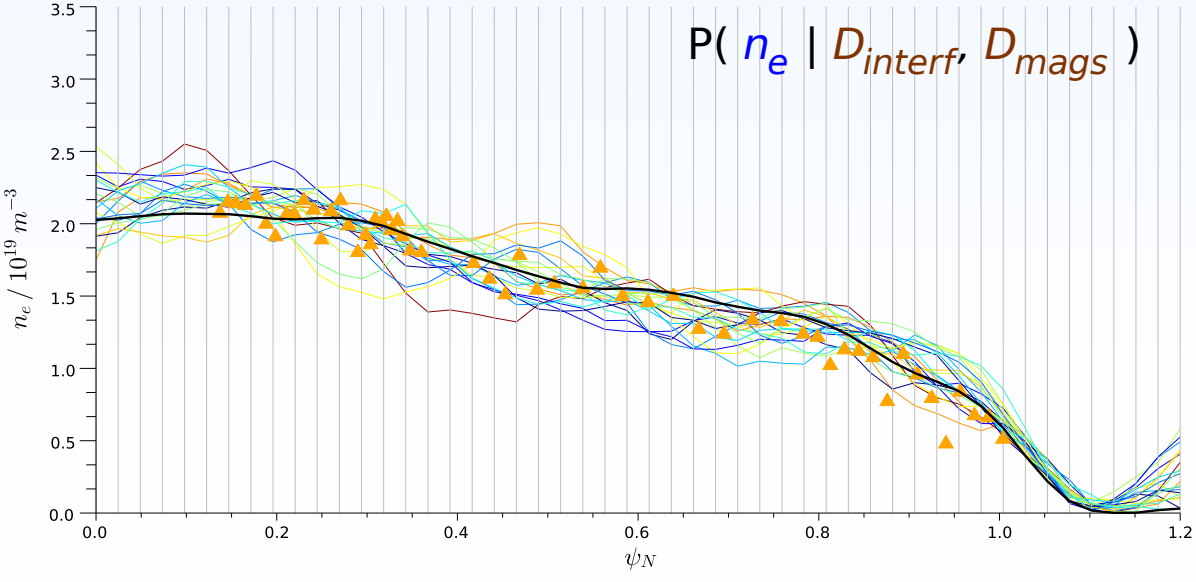

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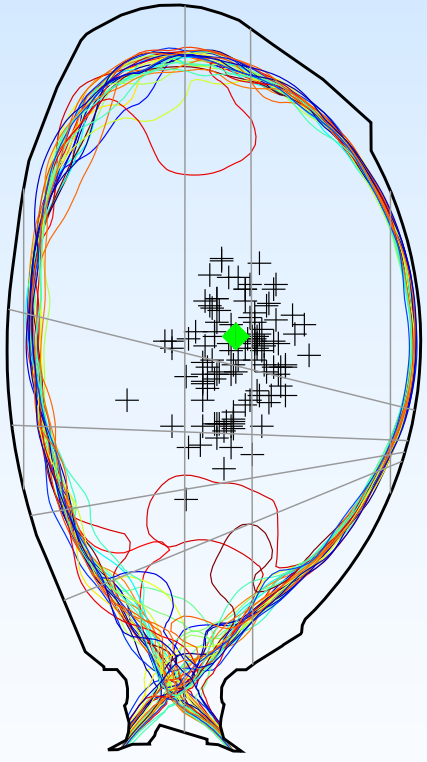

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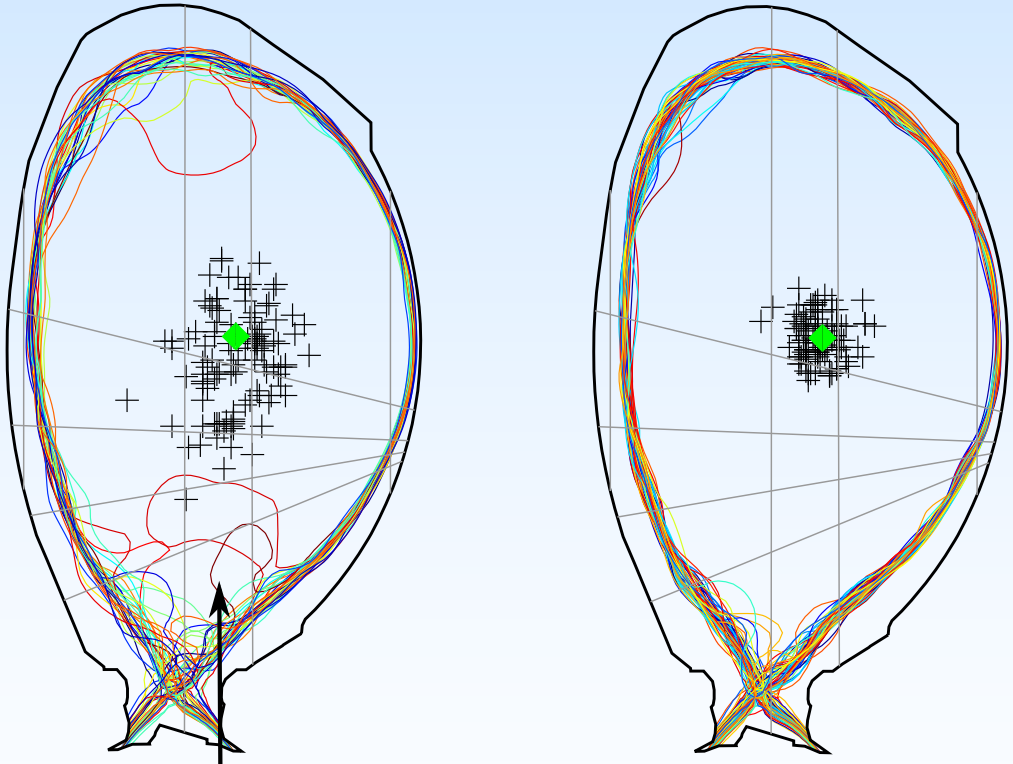

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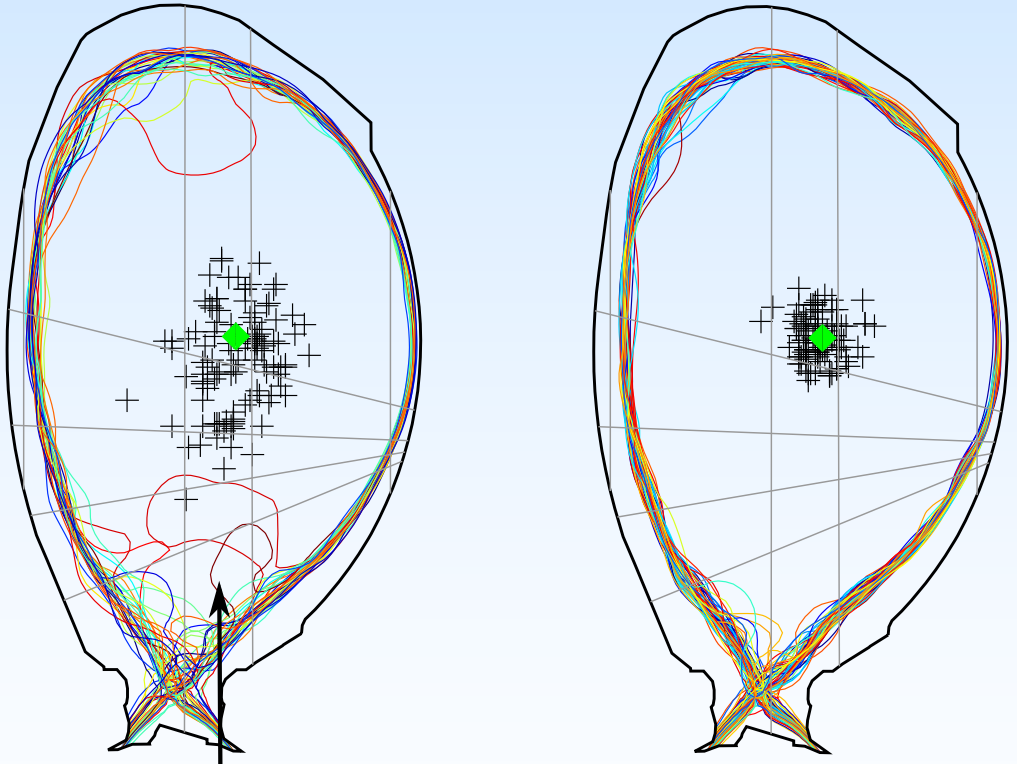

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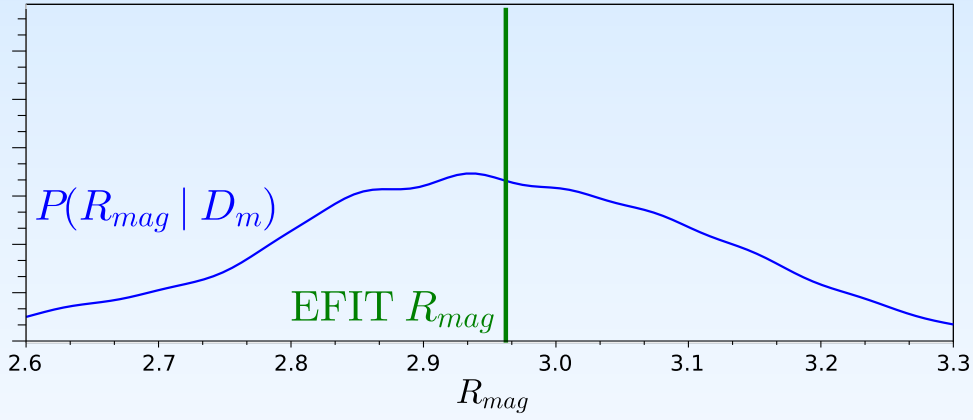

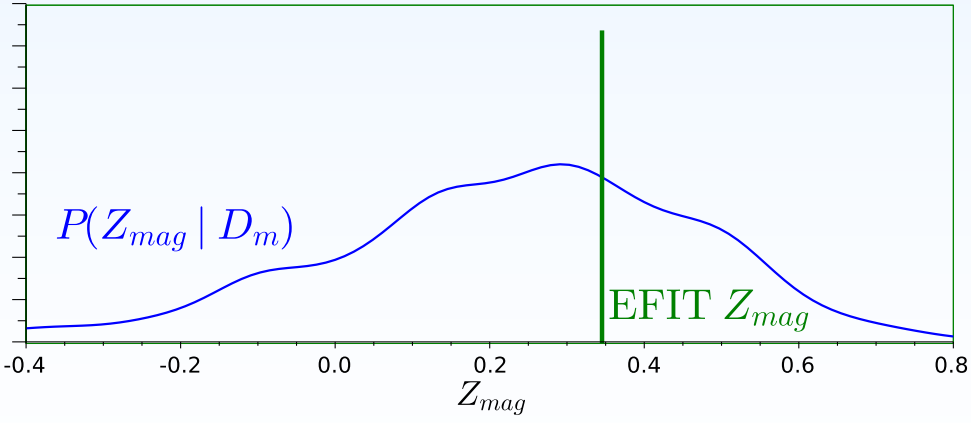

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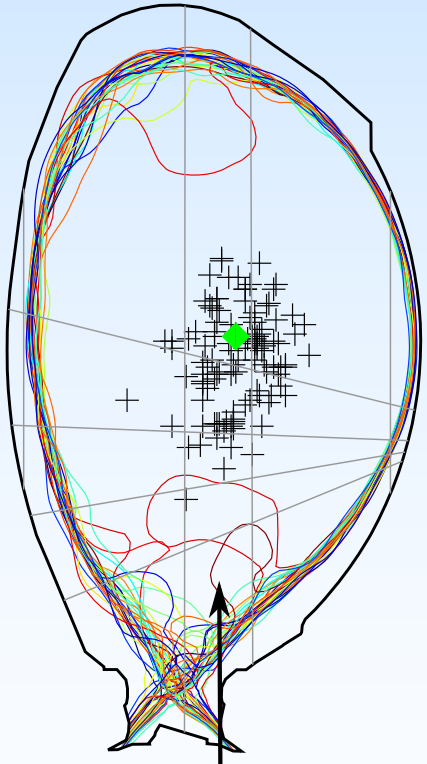

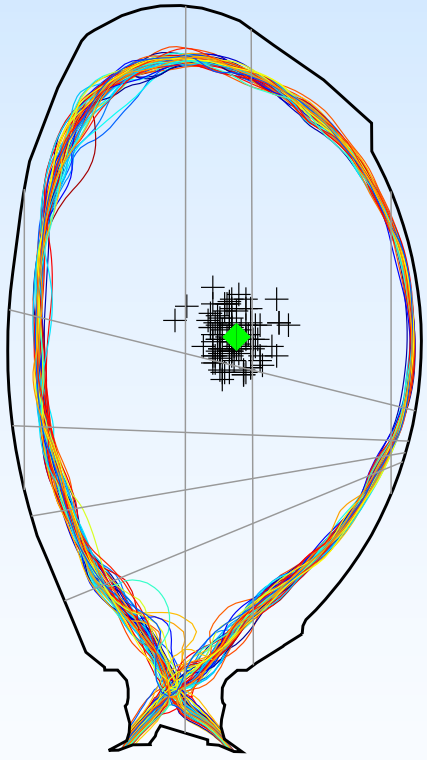

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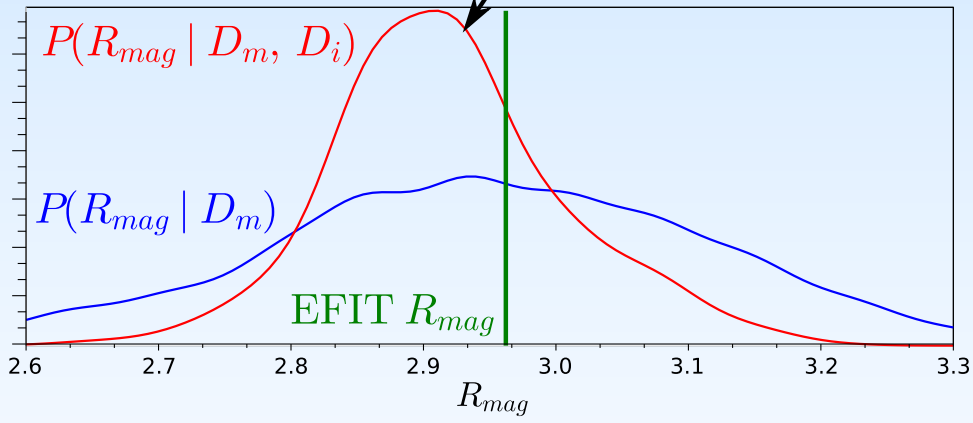
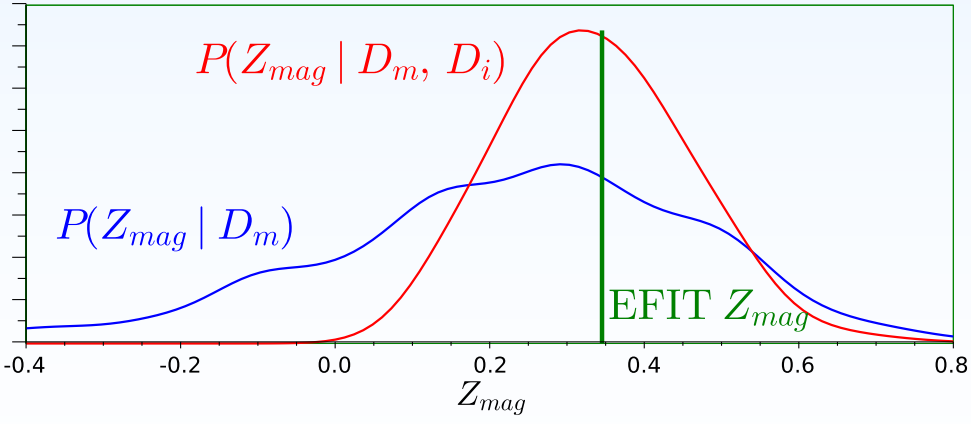
Less obviously, gives higher certainty magnetic axis





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Polarimetry I

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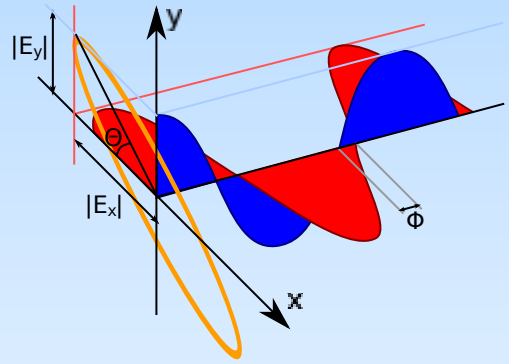
Depends primarily on n_e and $\boldsymbol{B}$.



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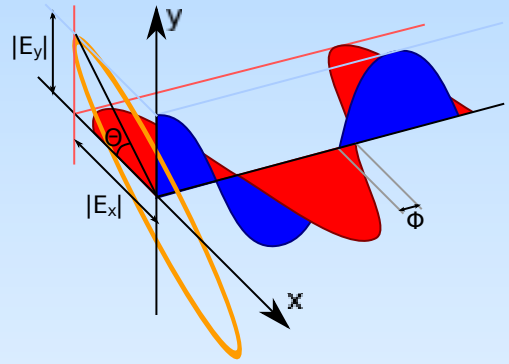

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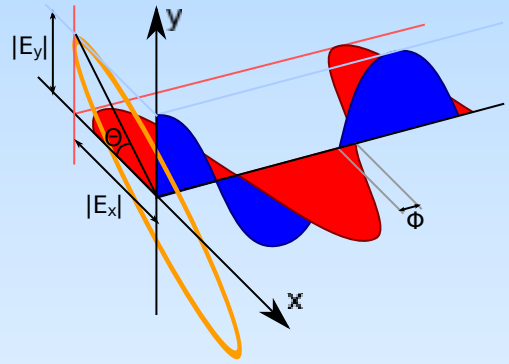

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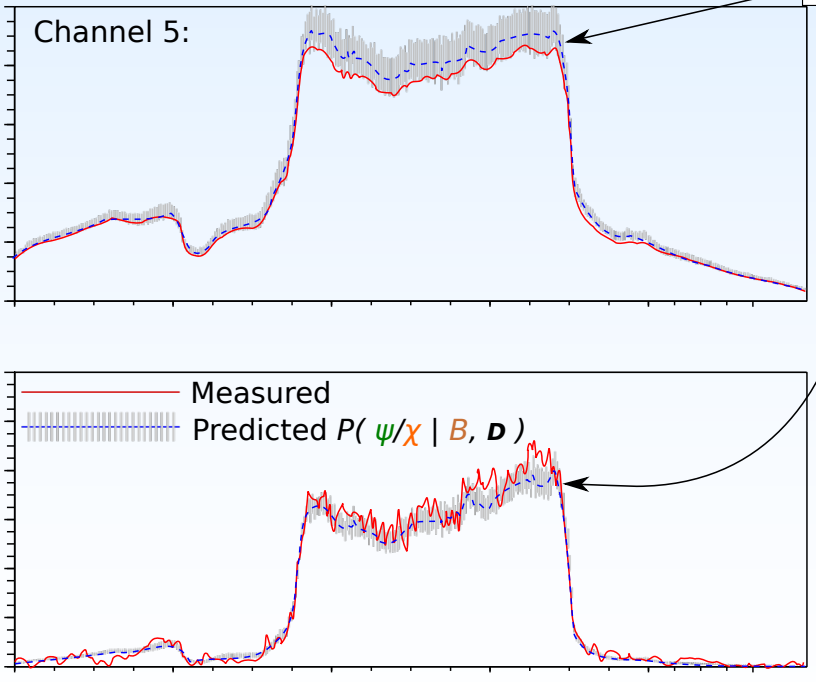

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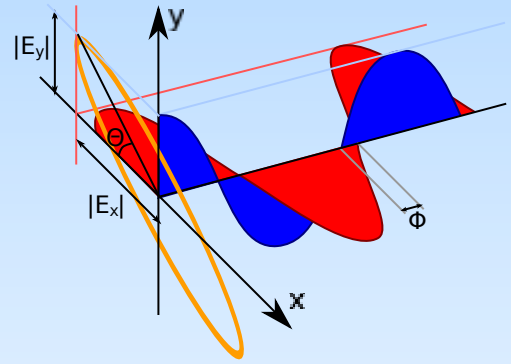

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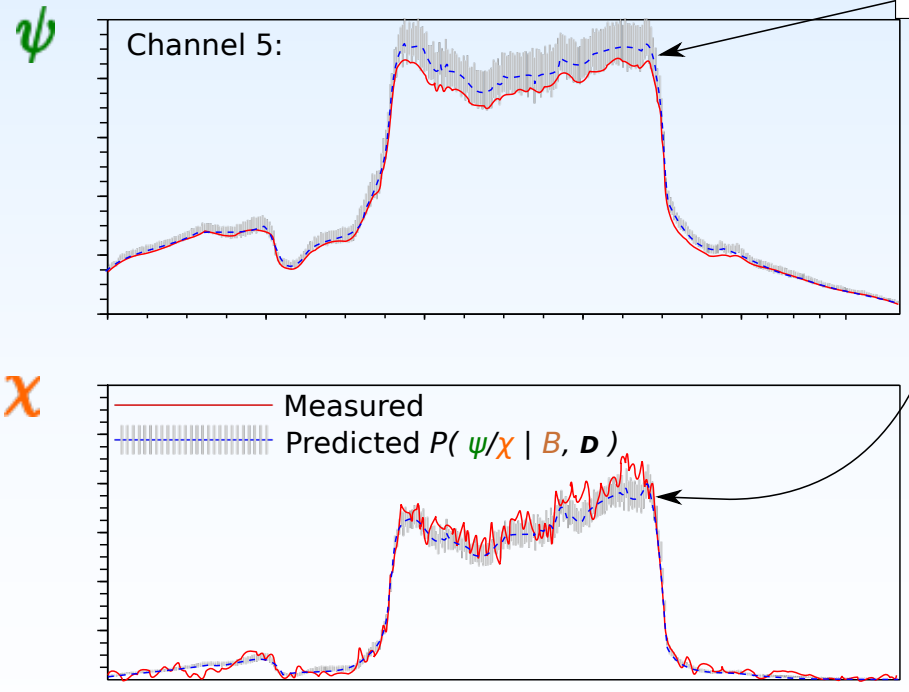

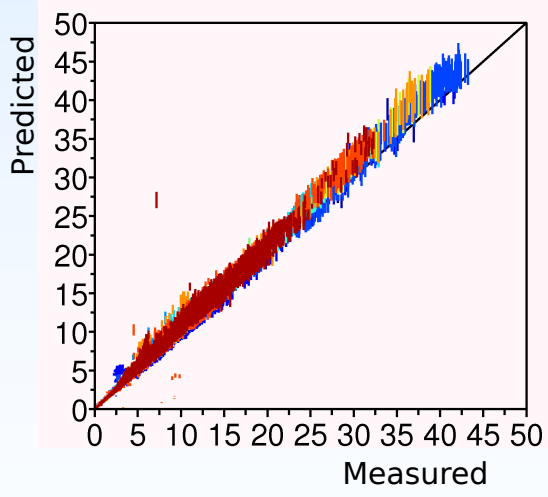

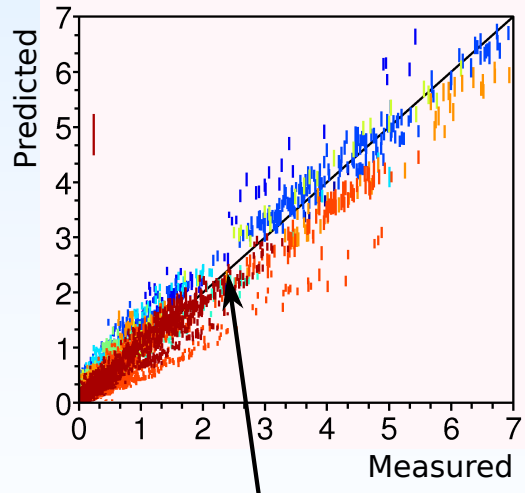

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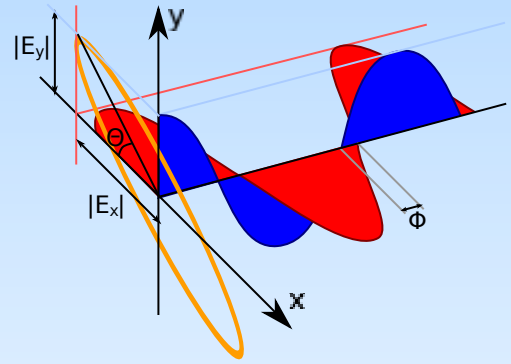

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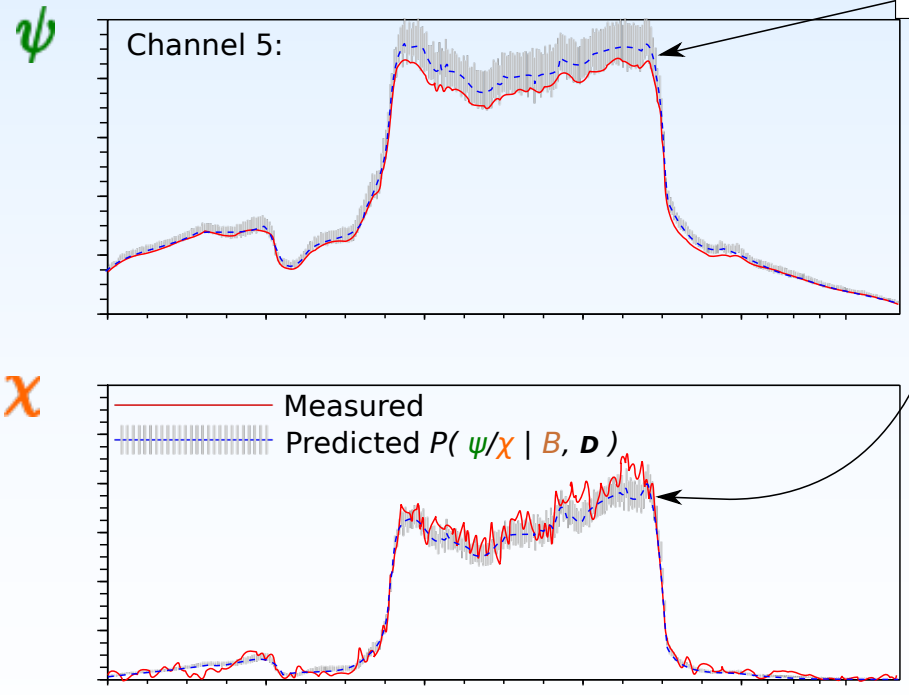

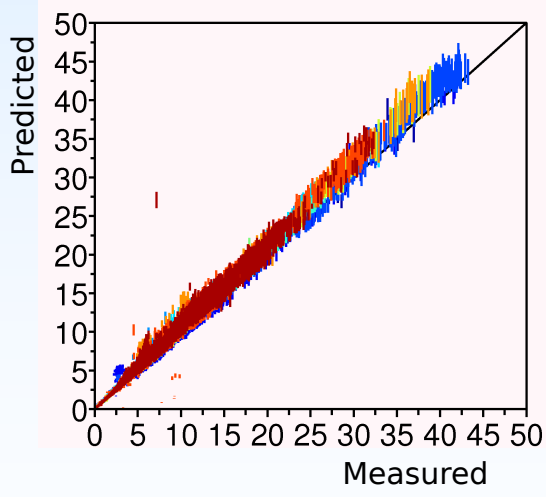

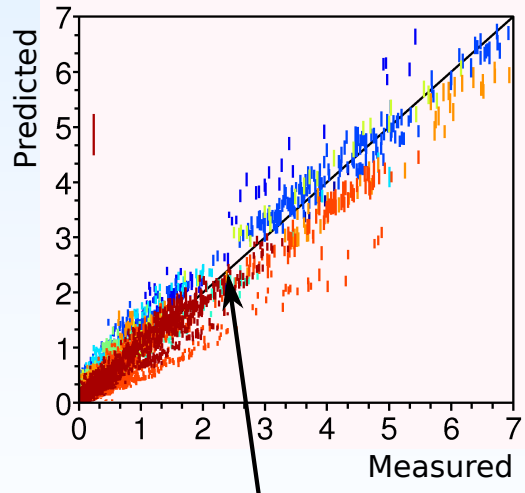

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Often, ψ and χ approximated by 'Faraday' and 'Cotton-Mouton' effects, each valid in specific cases not generally true on JET. **Lots** of effort spent trying to 'correct' the calculations back to the full model. Leads to confusing mix of terminology and unnecessary inaccuracy that gets confused with real diagnostic uncertainty.

Polarimetry II - High Temperature Models A

As well as 'cold plasma' model (fluid approx), two papers gave 'corrections' for high-T_e effects (quoted as large for T_e > ~5keV) derived from kinetic theory.

a) S.E. Segre (2002): Argues non-relativistic kinetic approximation is sufficient.

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Uncertainty due to calibration is much larger than model differences and is systematic for entire pulses:

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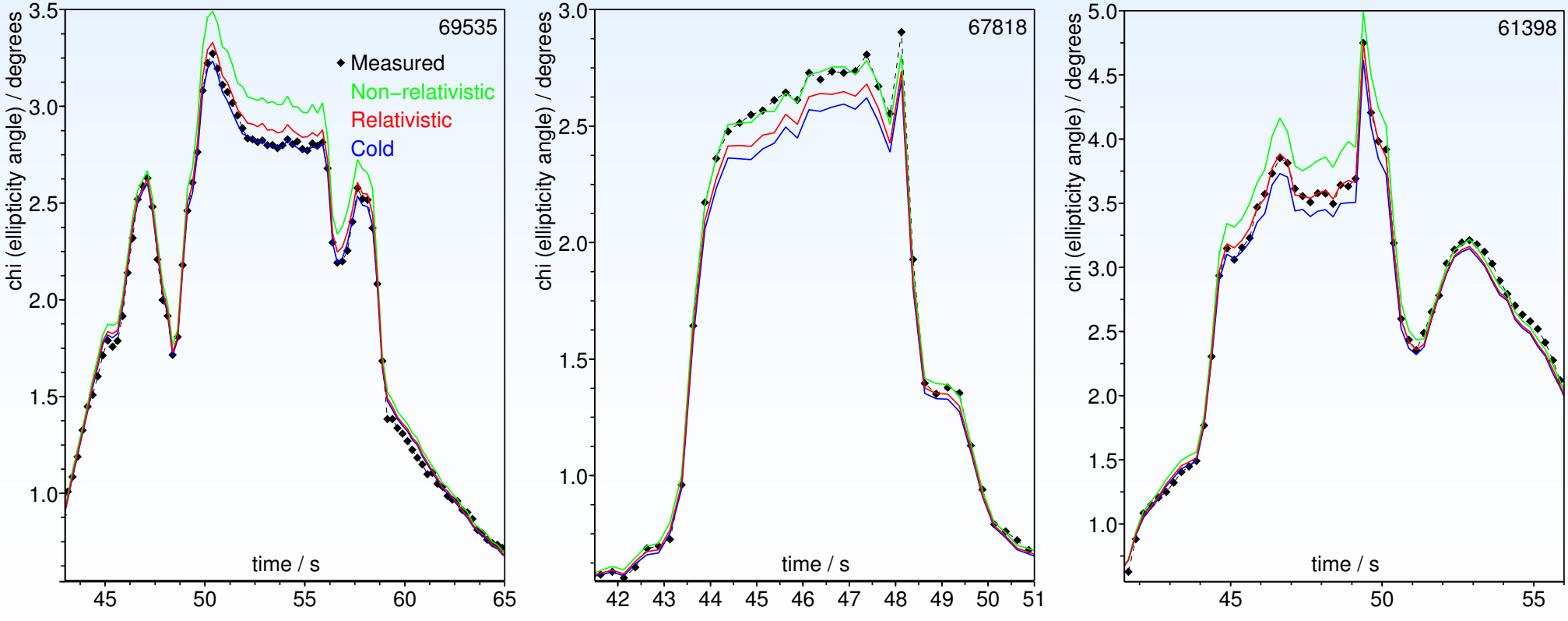

Can easily find pulses that agree with any model.

Polarimetry III - High Temperature Models B

Solutions: Run session of pulses at very high T_e to get ~10 pulses with effect bigger than uncertainty?

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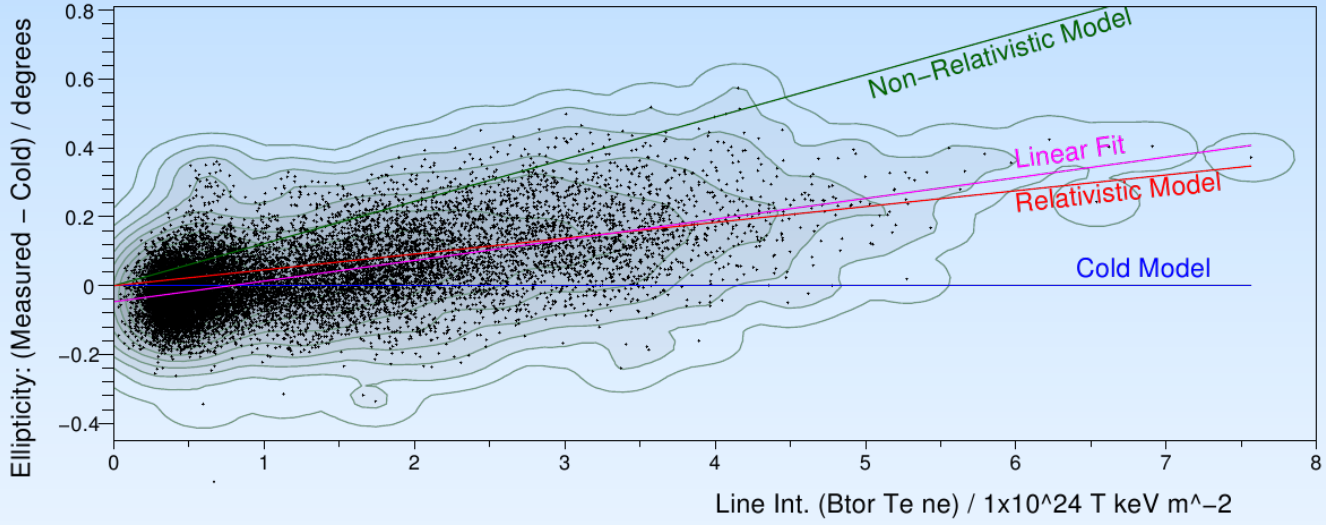

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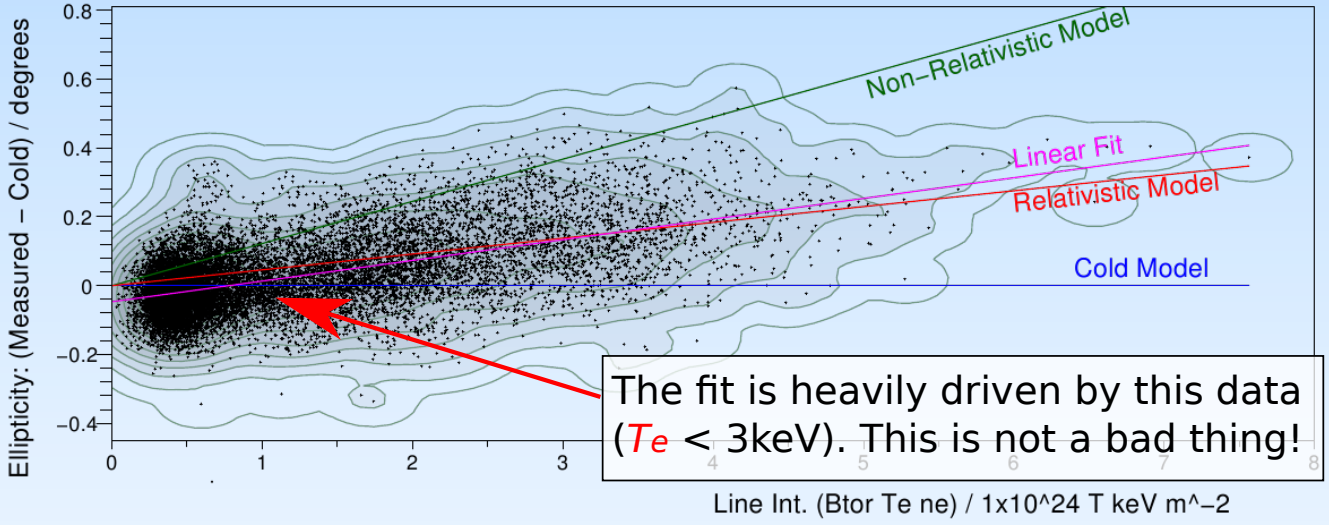

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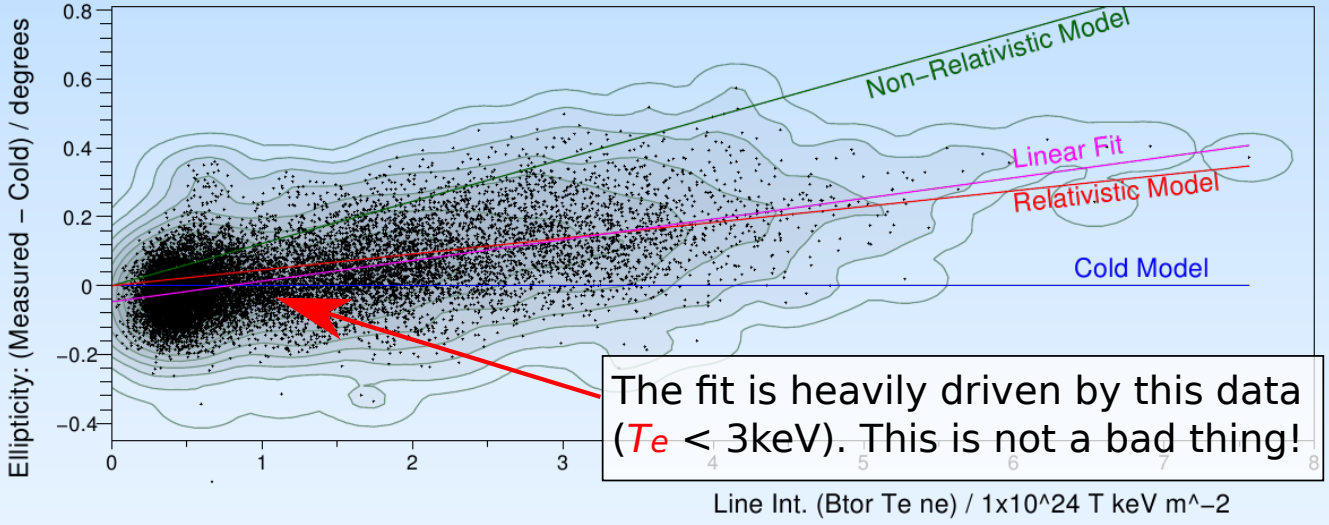

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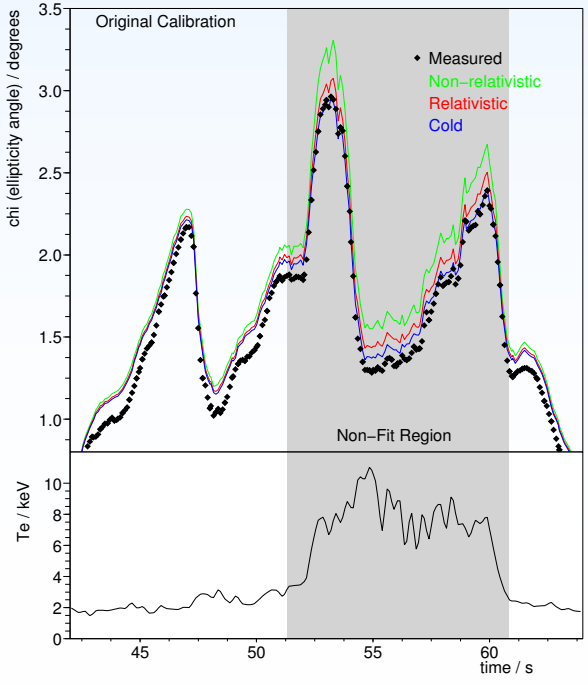
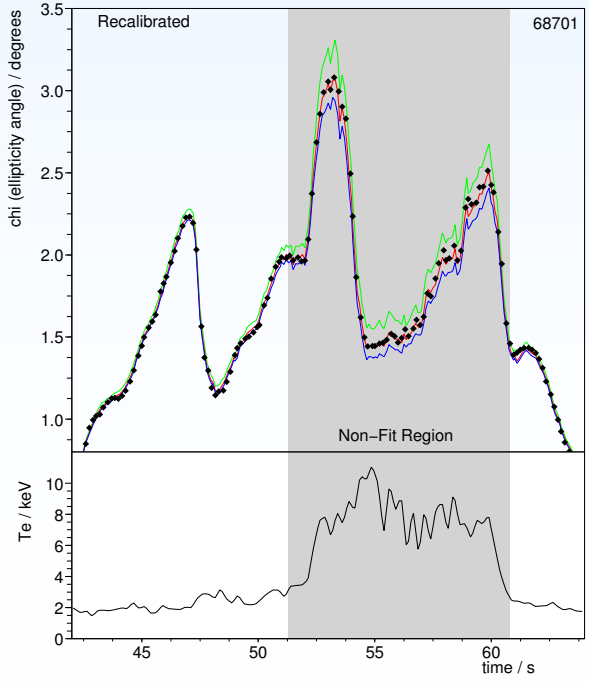




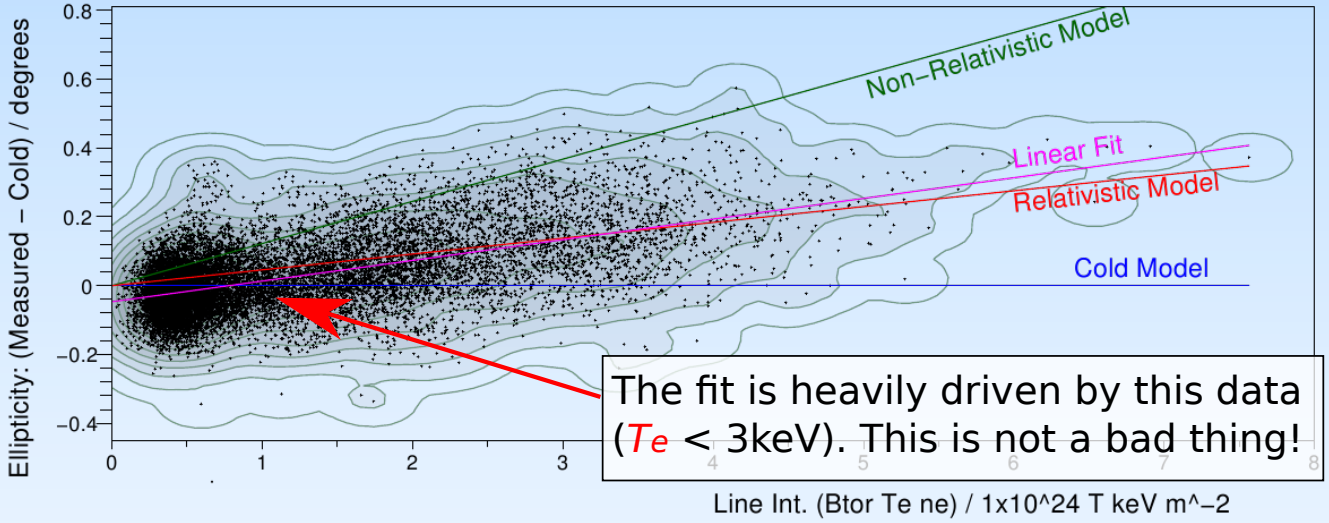
For some pulses:
1) Use cold plasma model on cold plasma, to fix calibration params of forward model for diagnostic optics.
2) Compare data in high T_e period.

Polarimetry III - High Temperature Models B

Solutions: Run session of pulses at very high T_e to get ~10 pulses with effect bigger than uncertainty?

NO! Relativity **does not** '*switch on*' at 8keV.

Lot of stats --> accurate diagnostic:
10,000 points with +/-50% is better than 10 points with +/-10%.
At JET, we have **LOTS** of stats!



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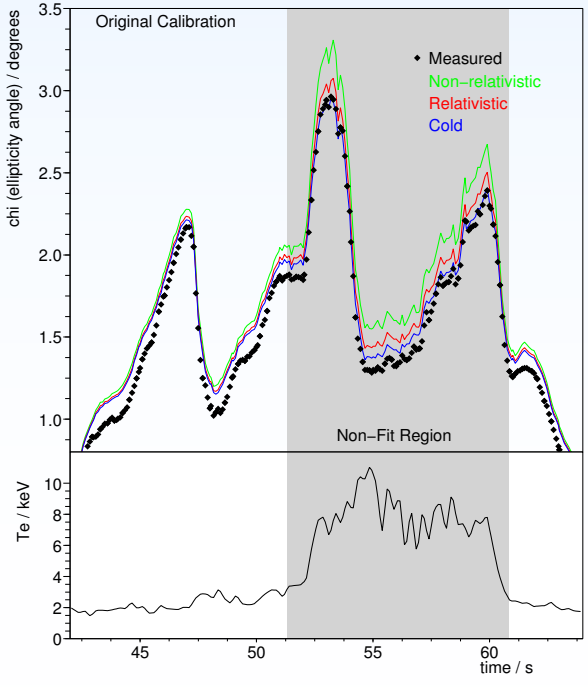

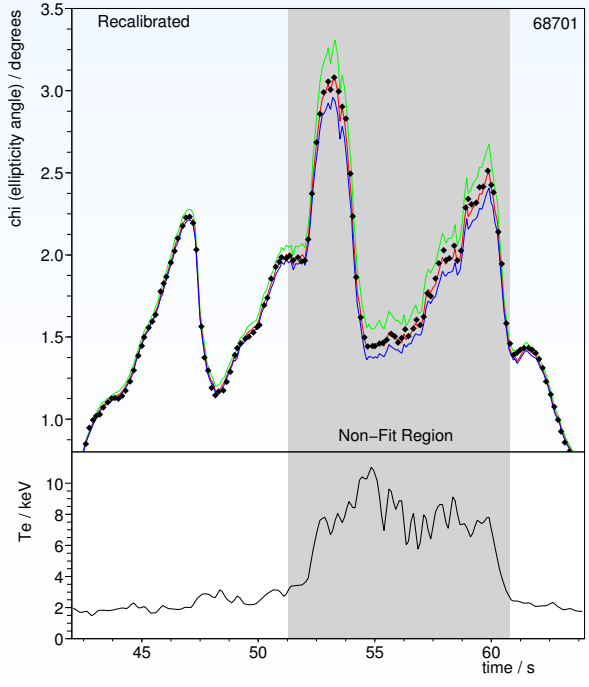

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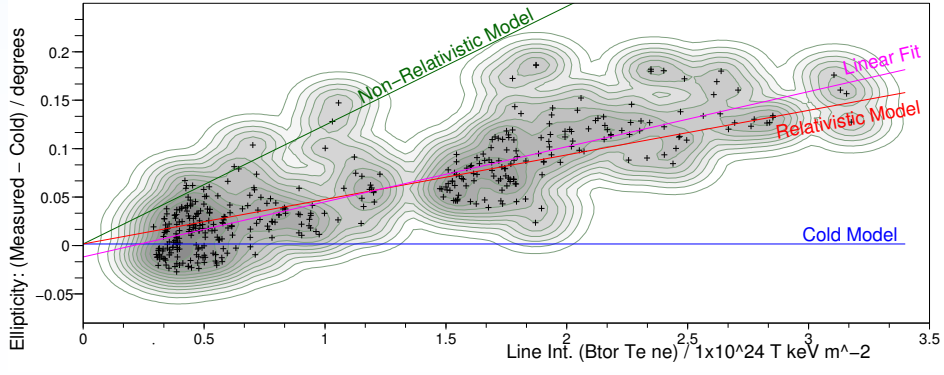

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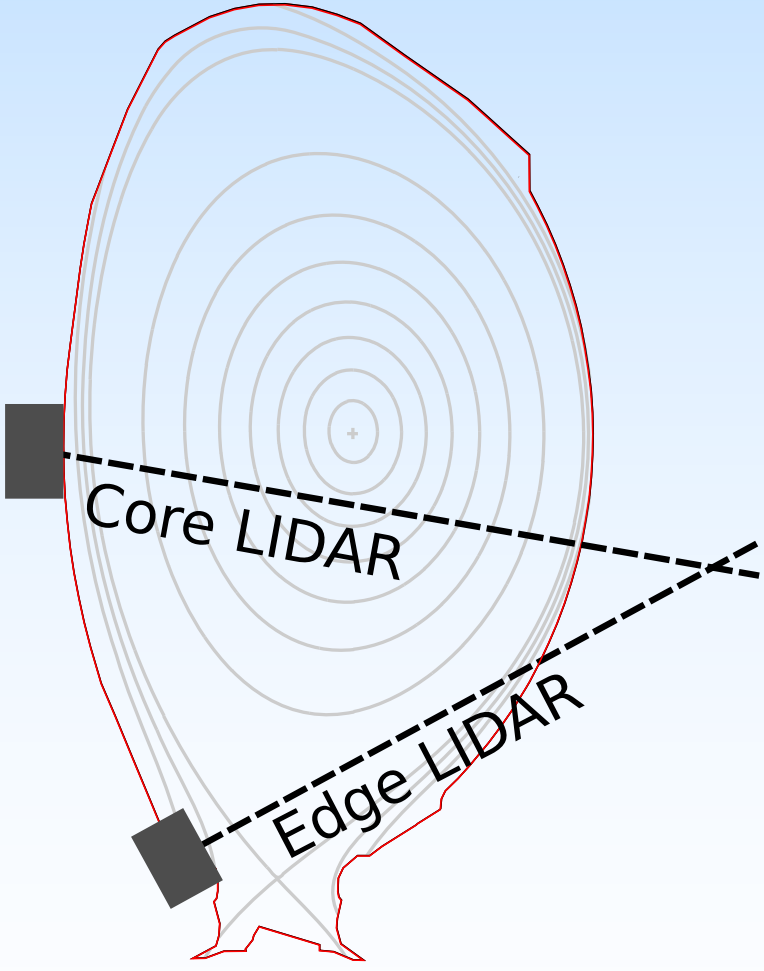

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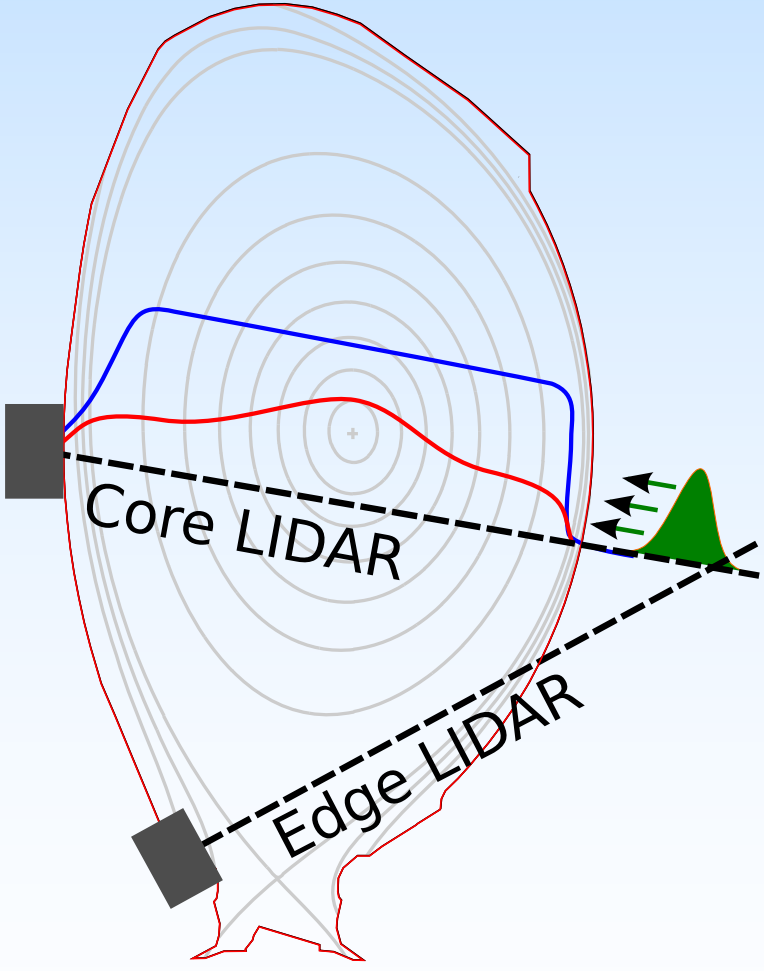

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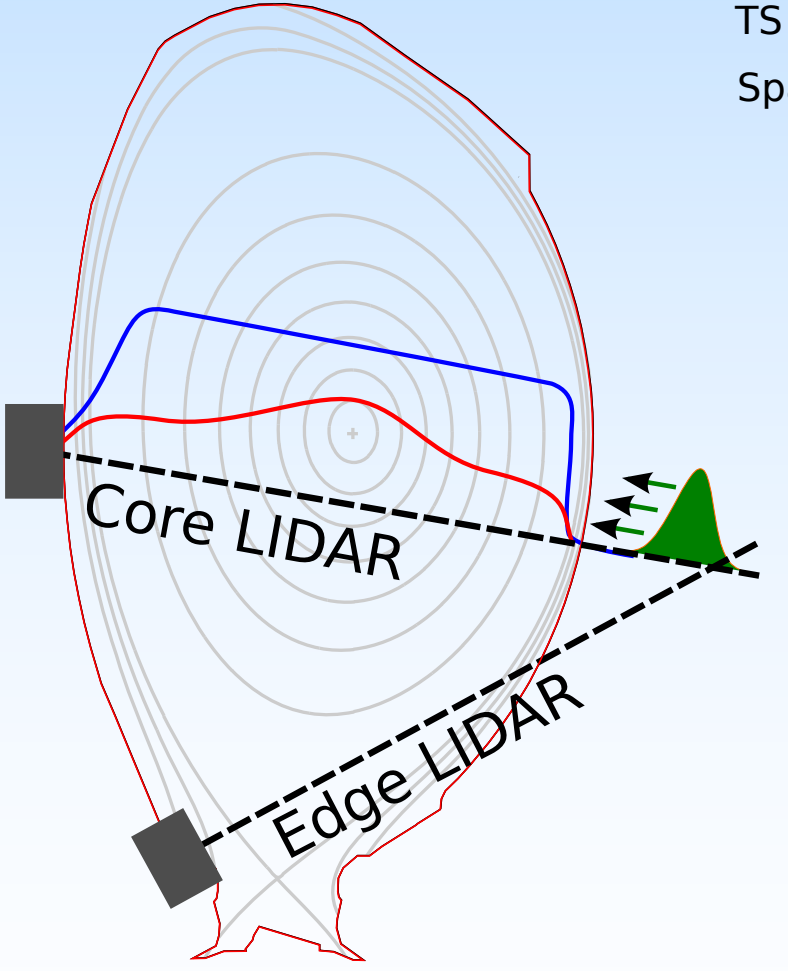

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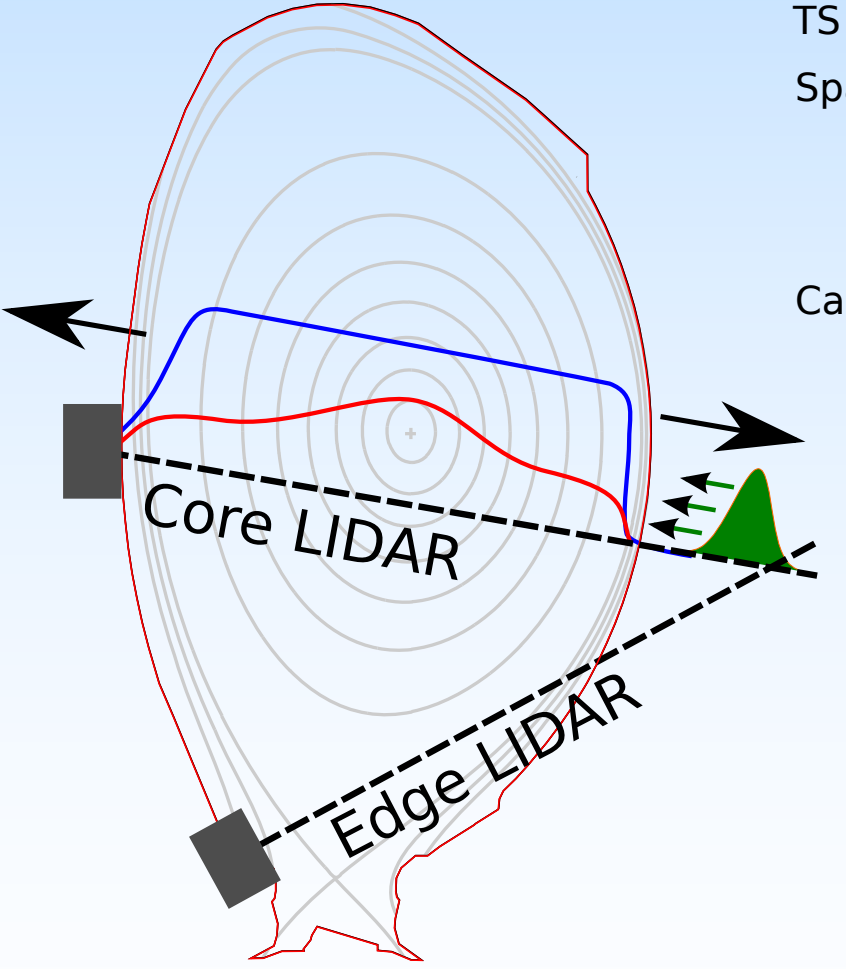

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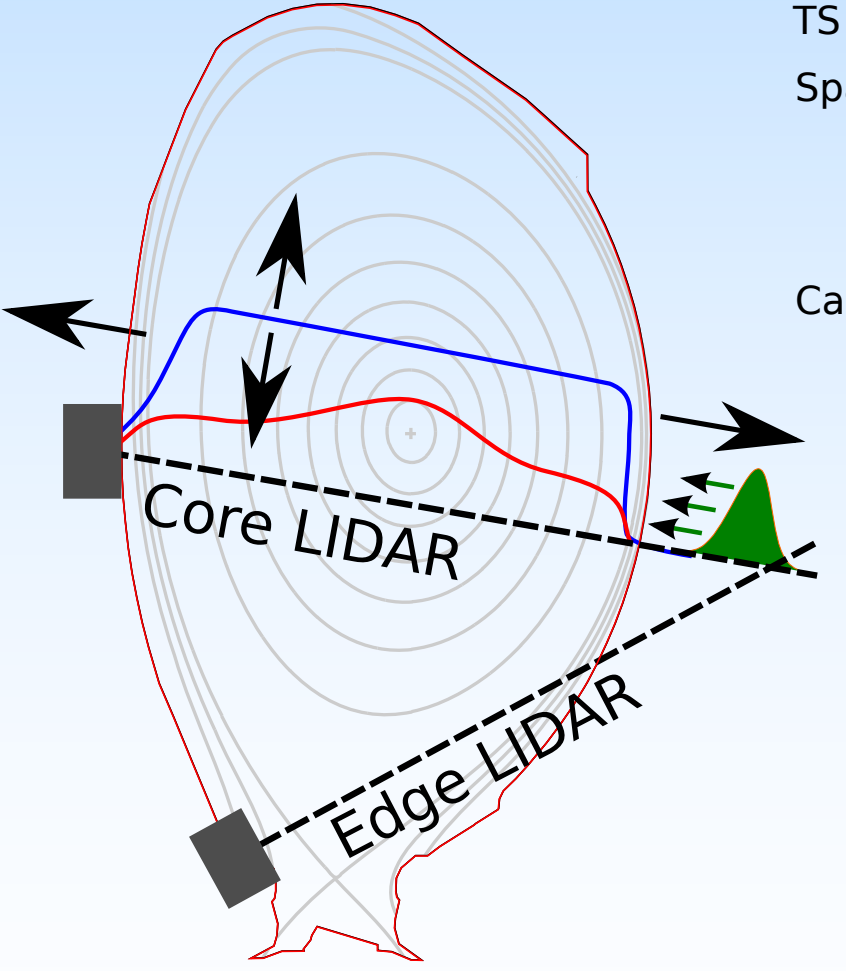

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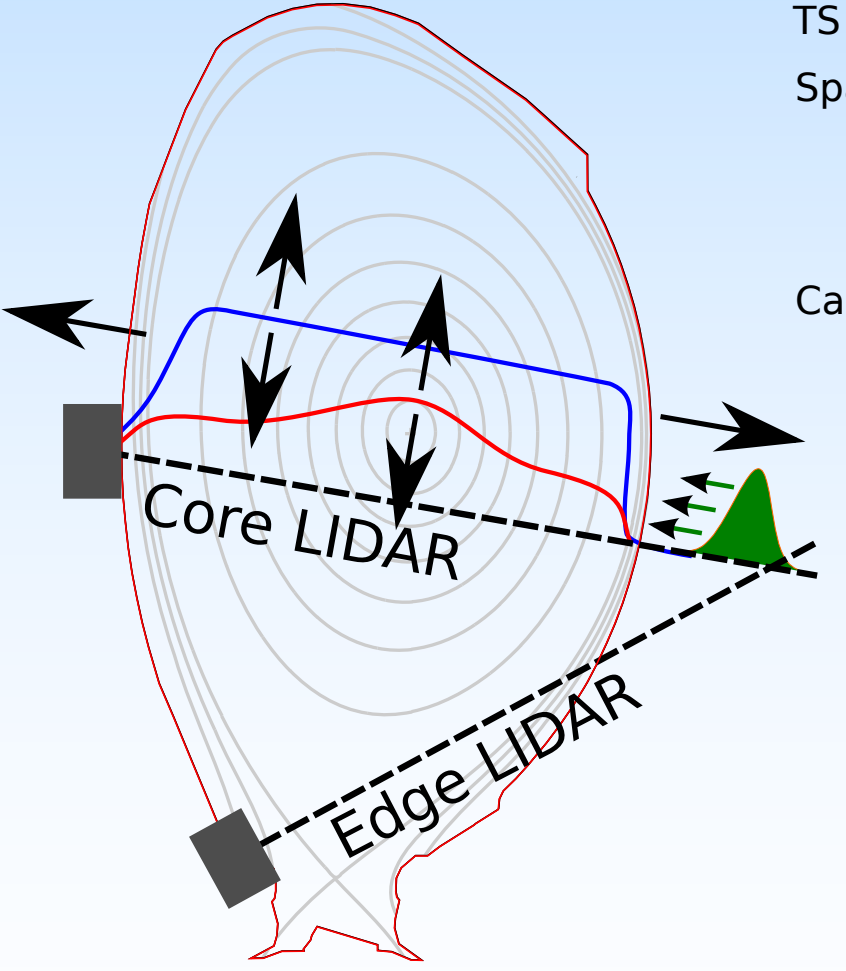

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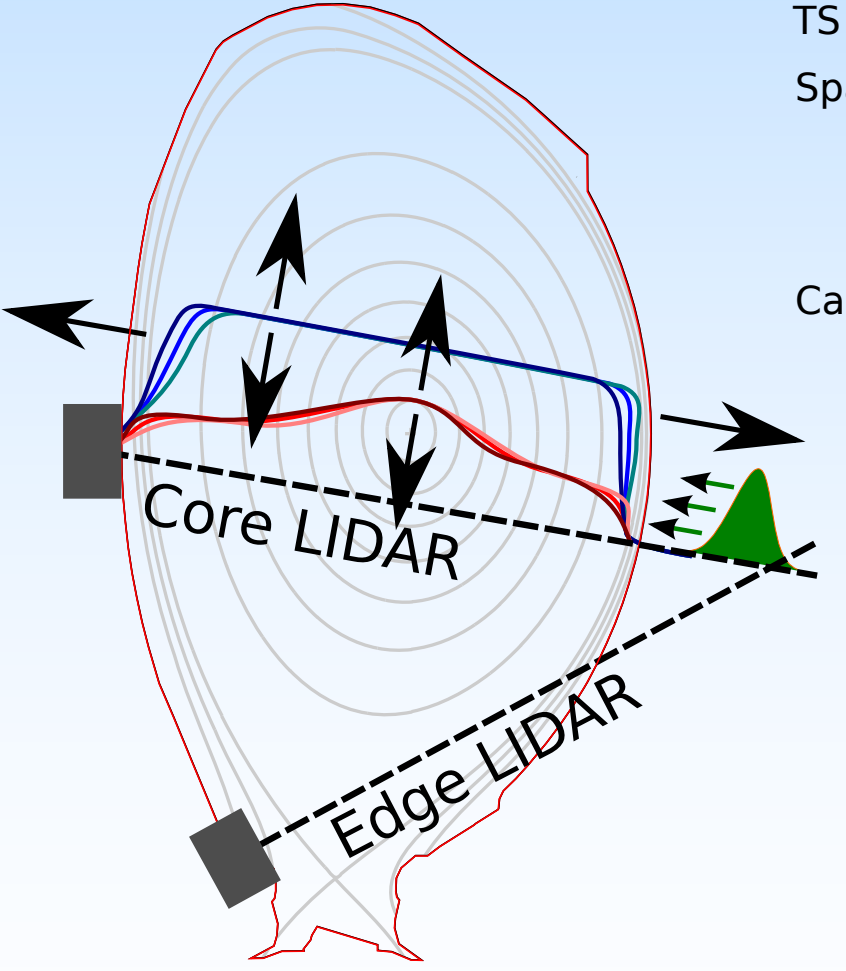

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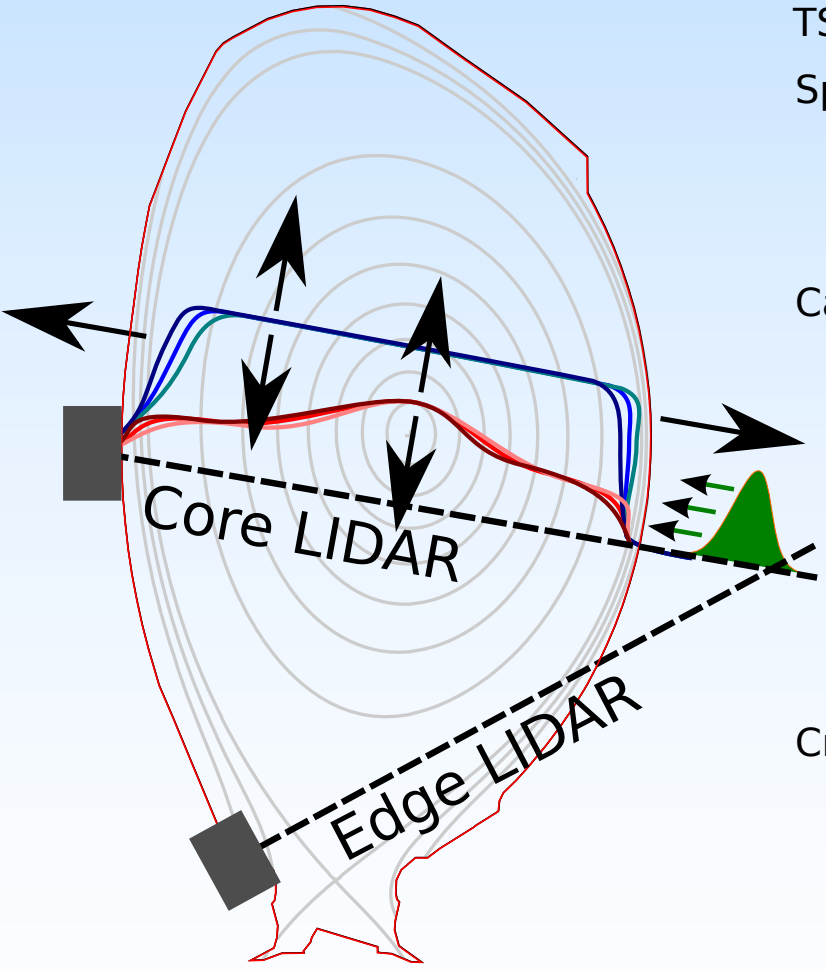

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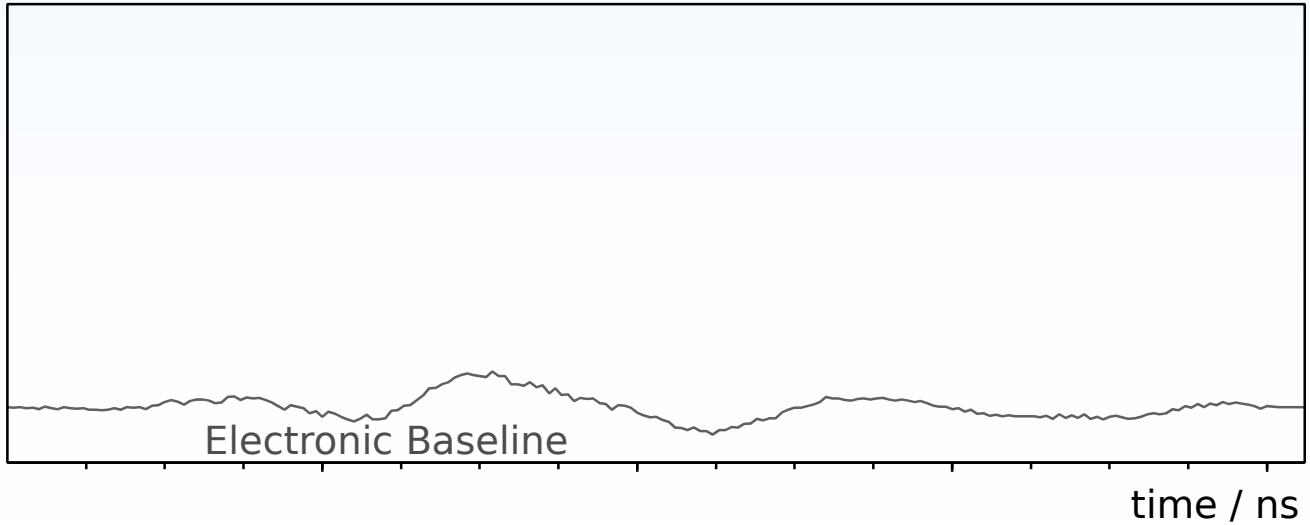

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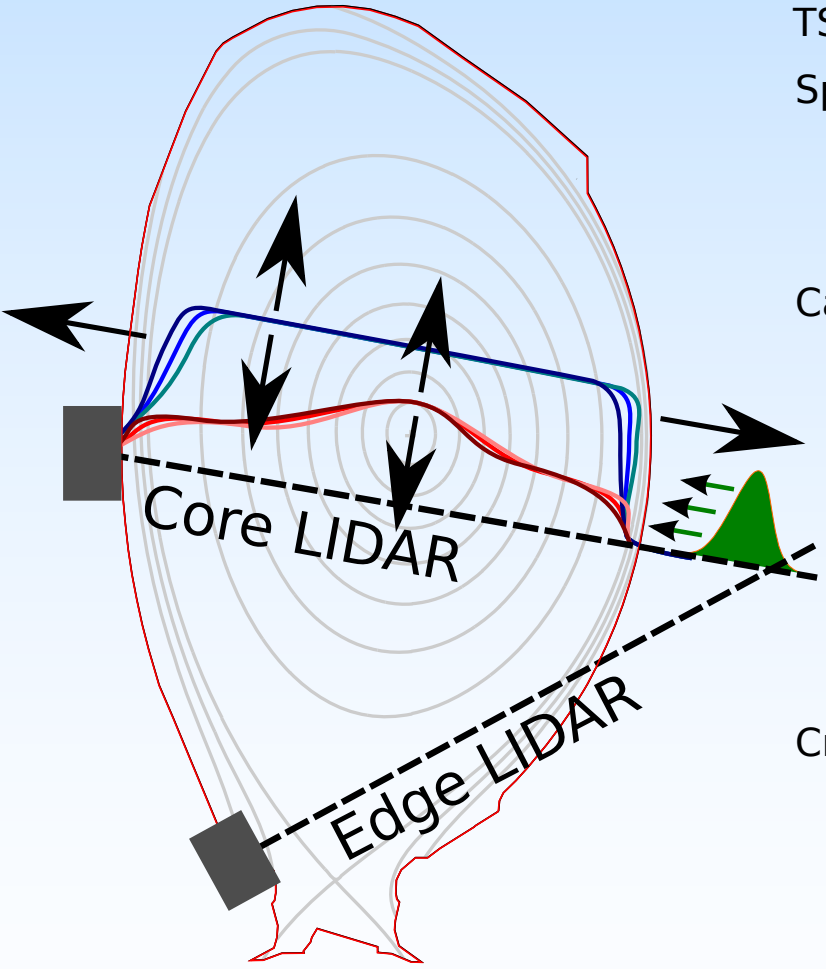

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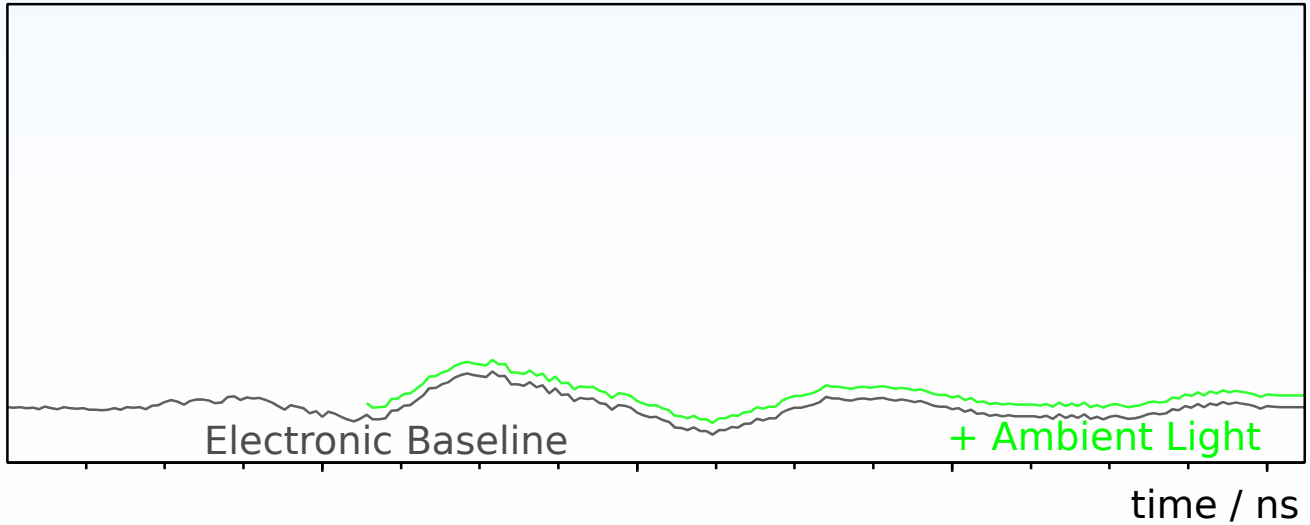

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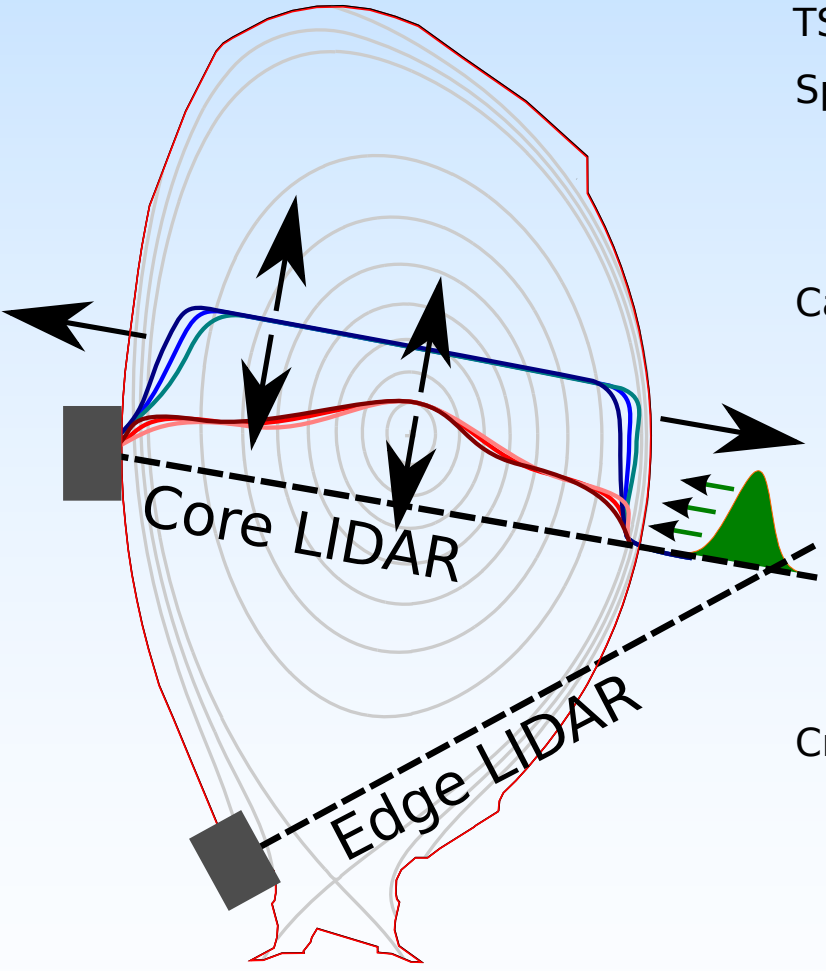

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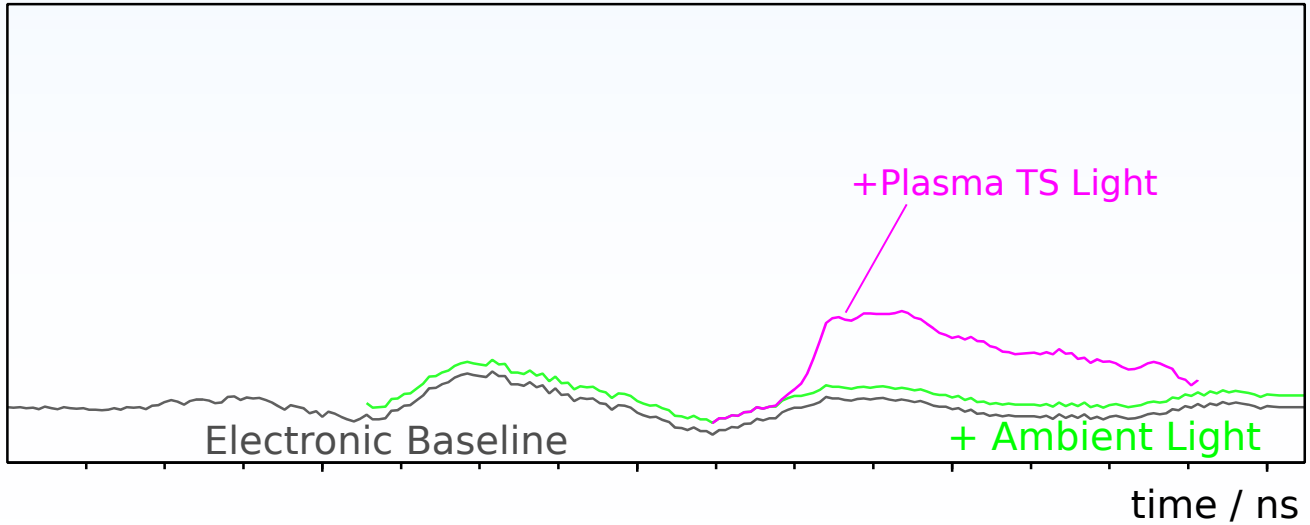

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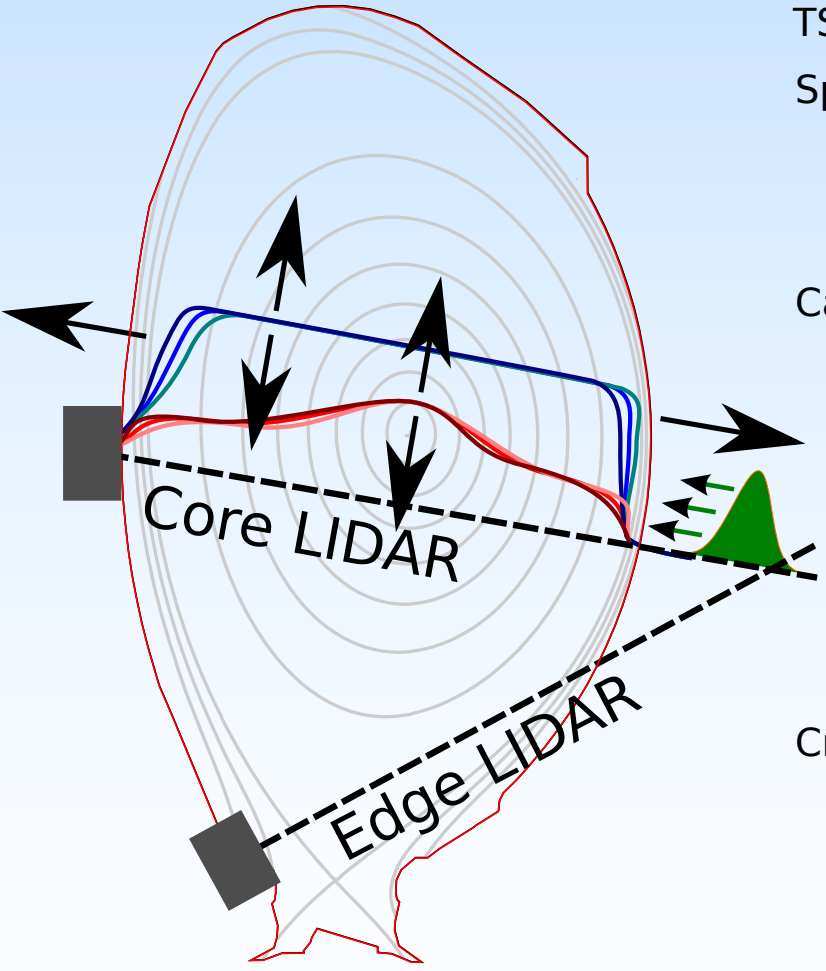

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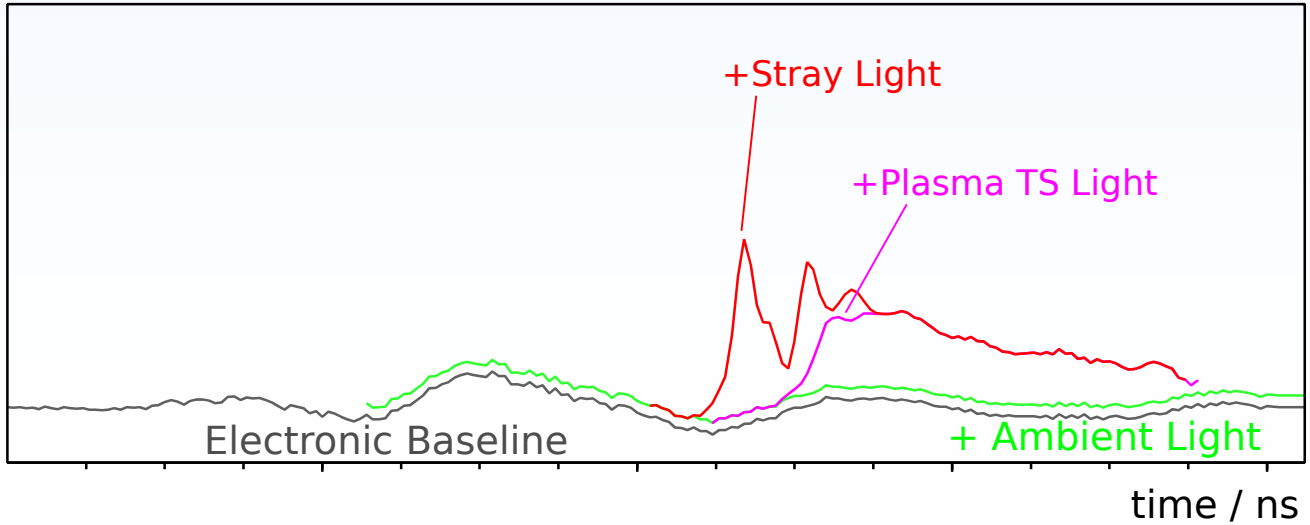

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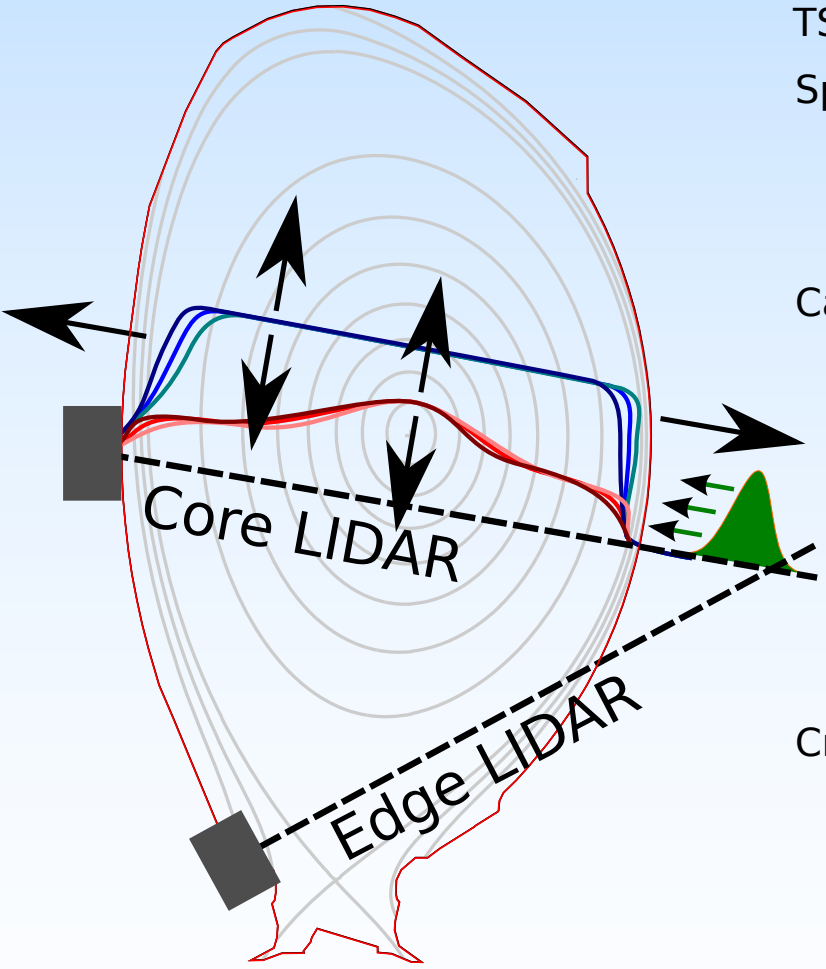

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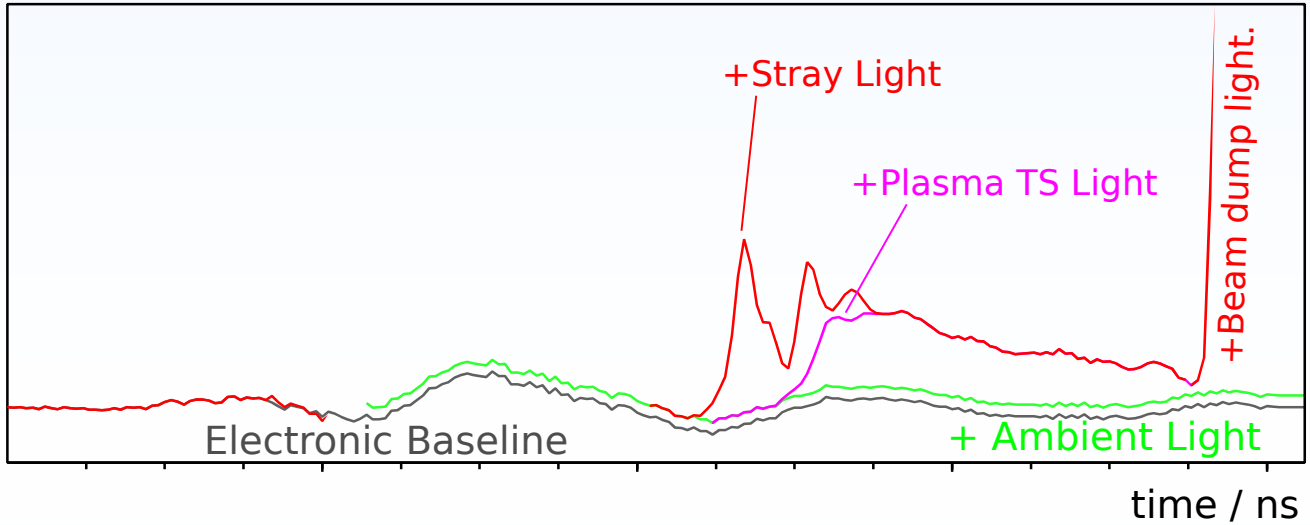

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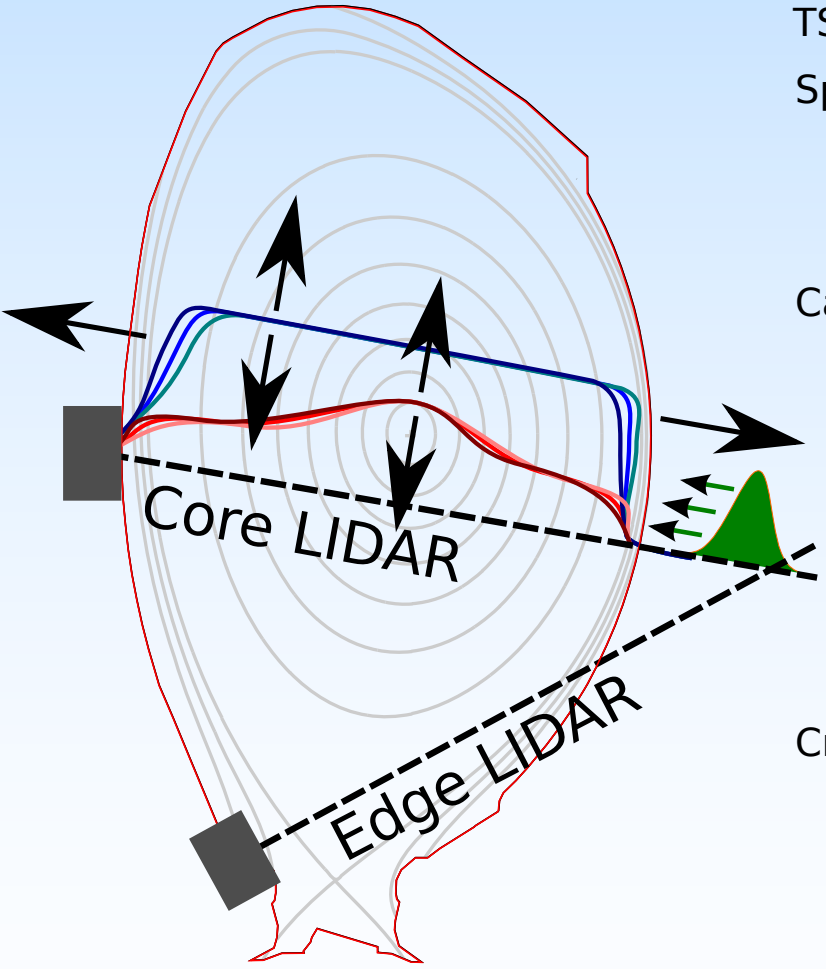

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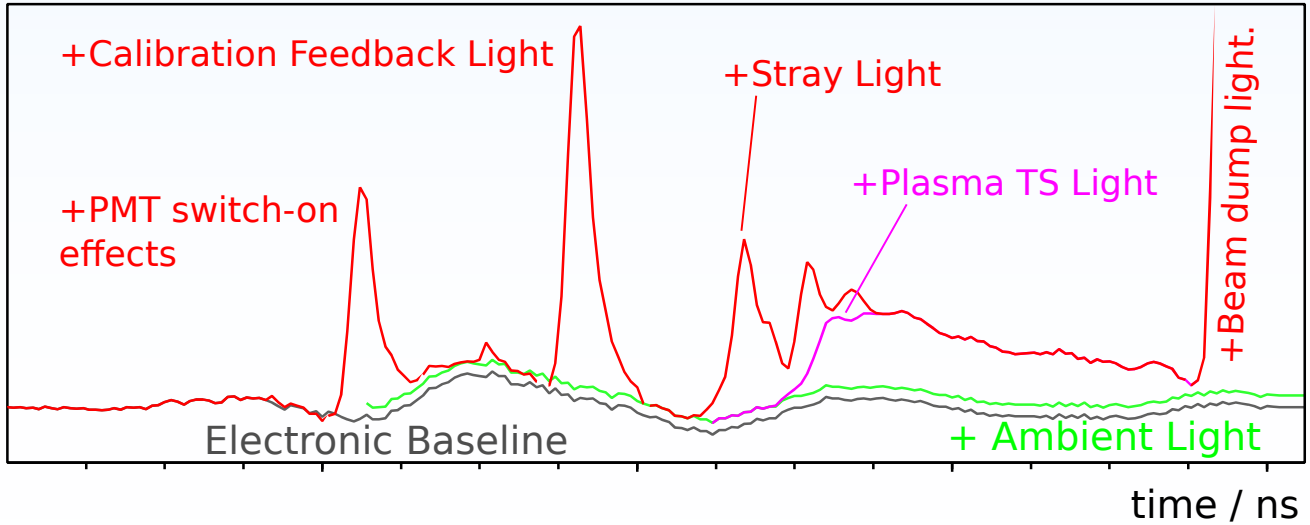

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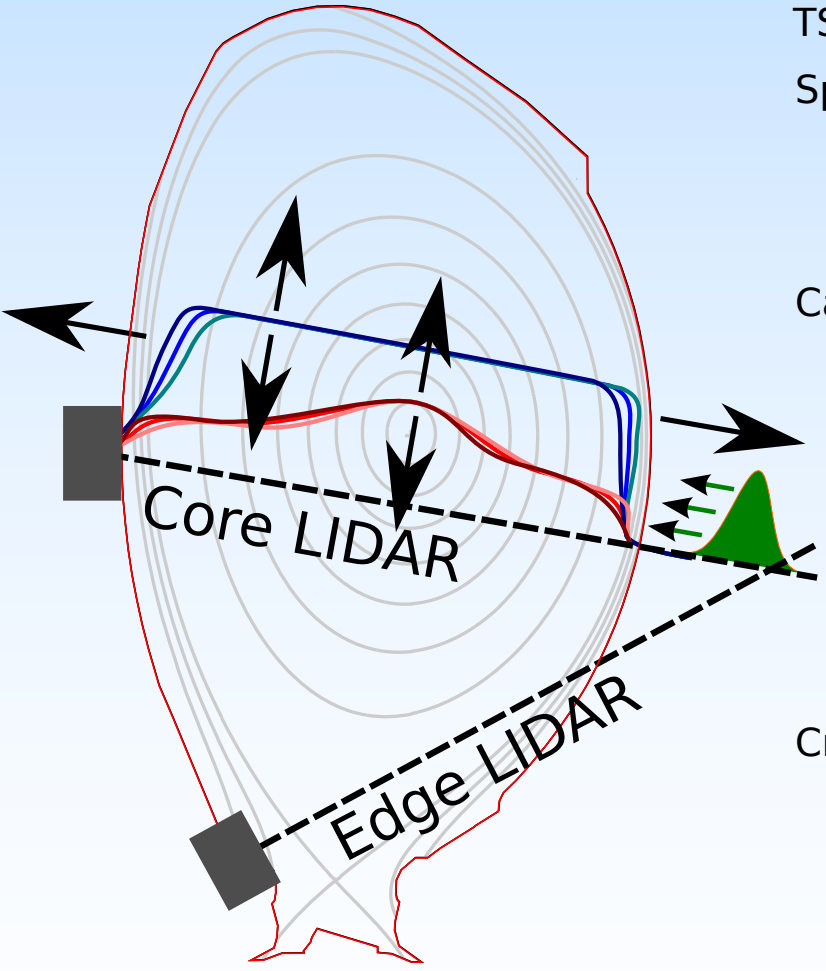

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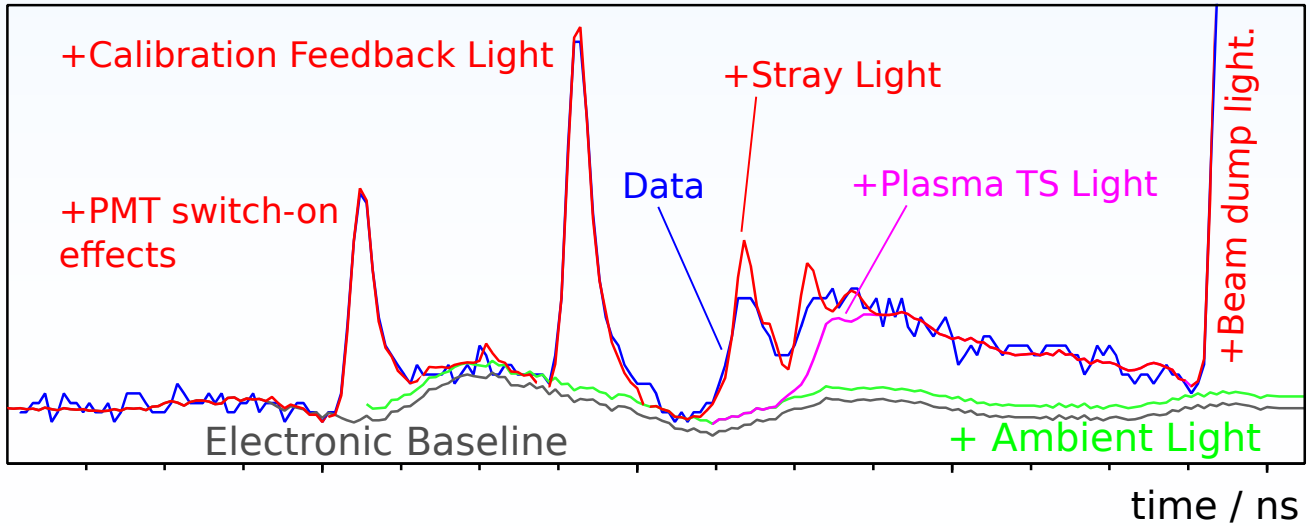

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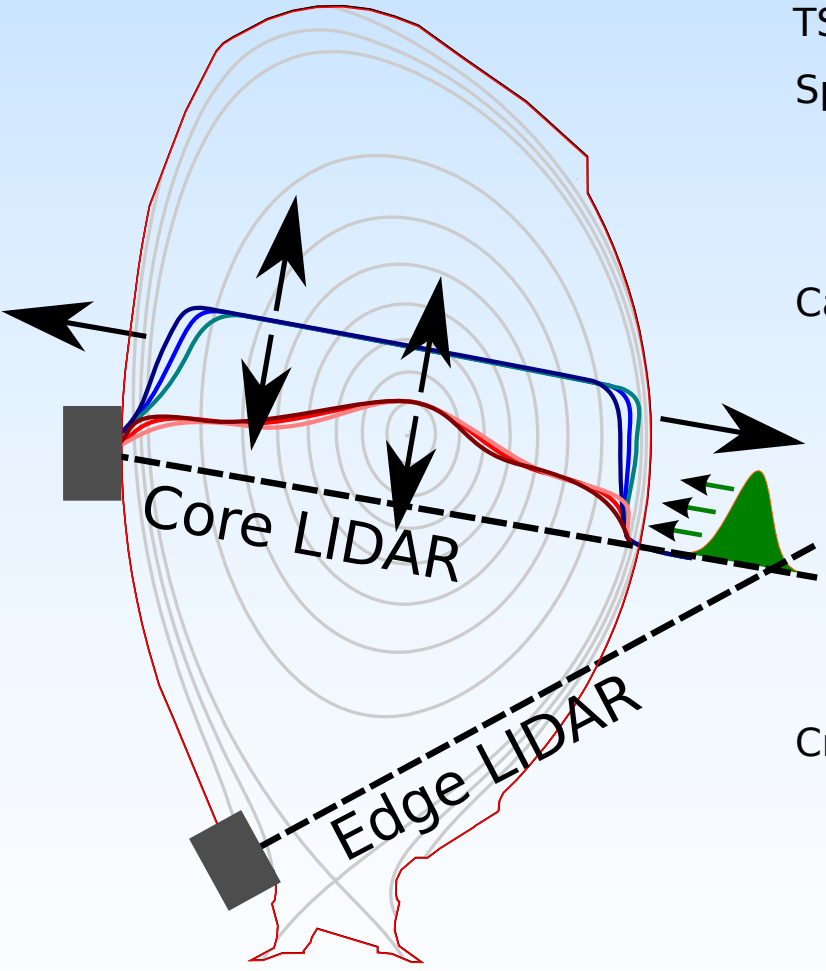

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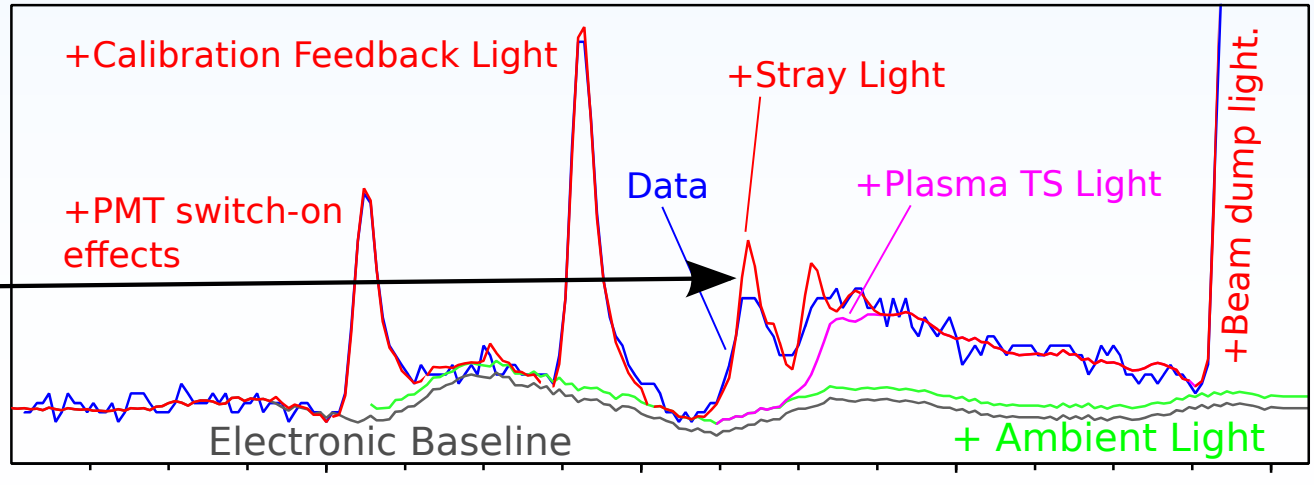

Stray light effects low signal (low ne) data on both systems but is **vital** for proper edge LIDAR analysis.

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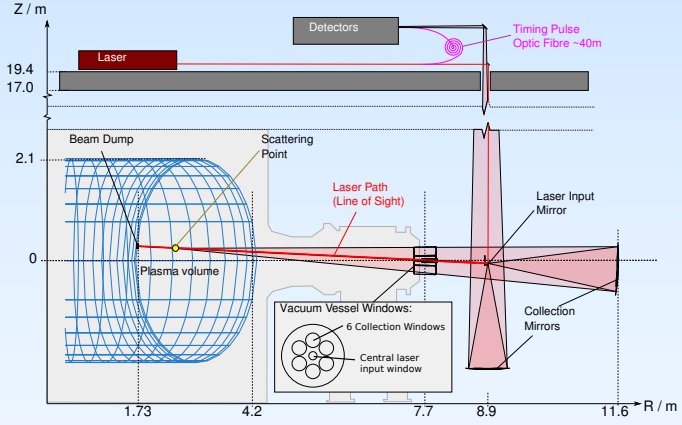

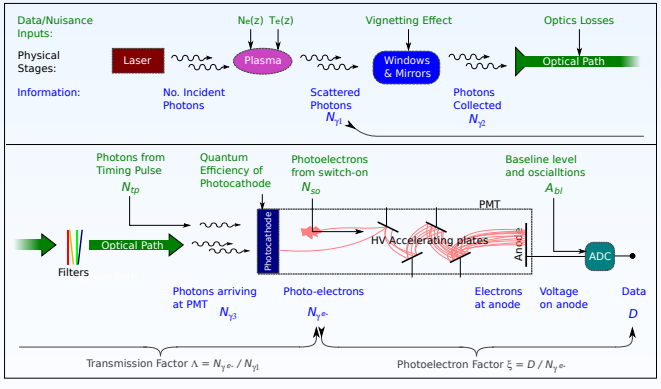

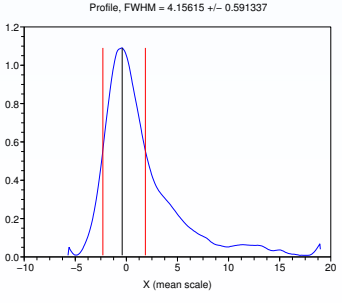

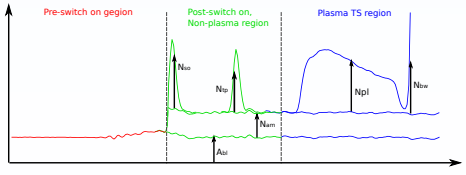

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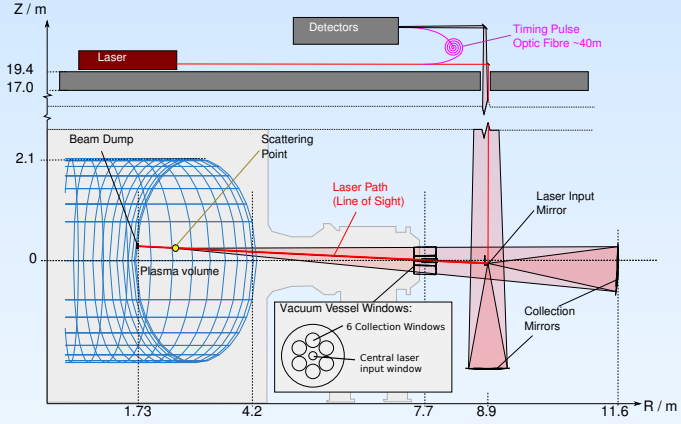

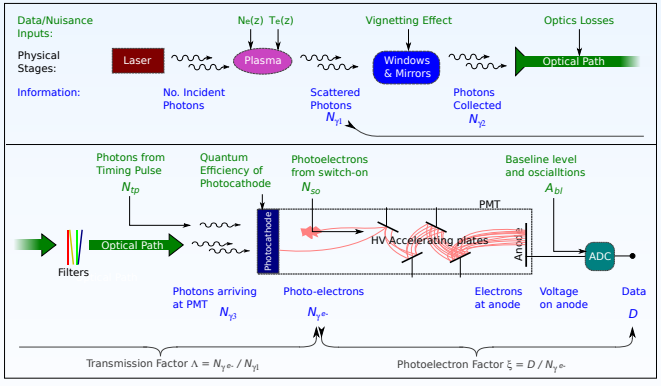

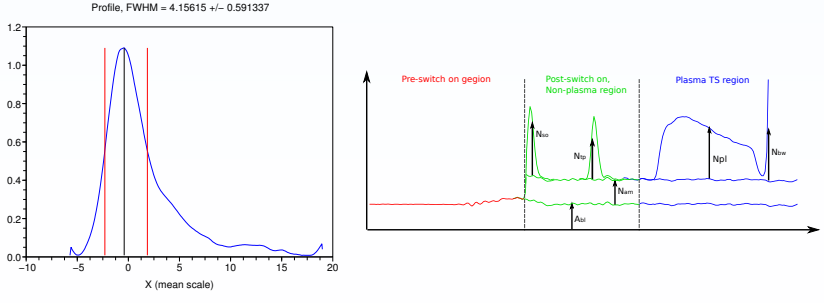

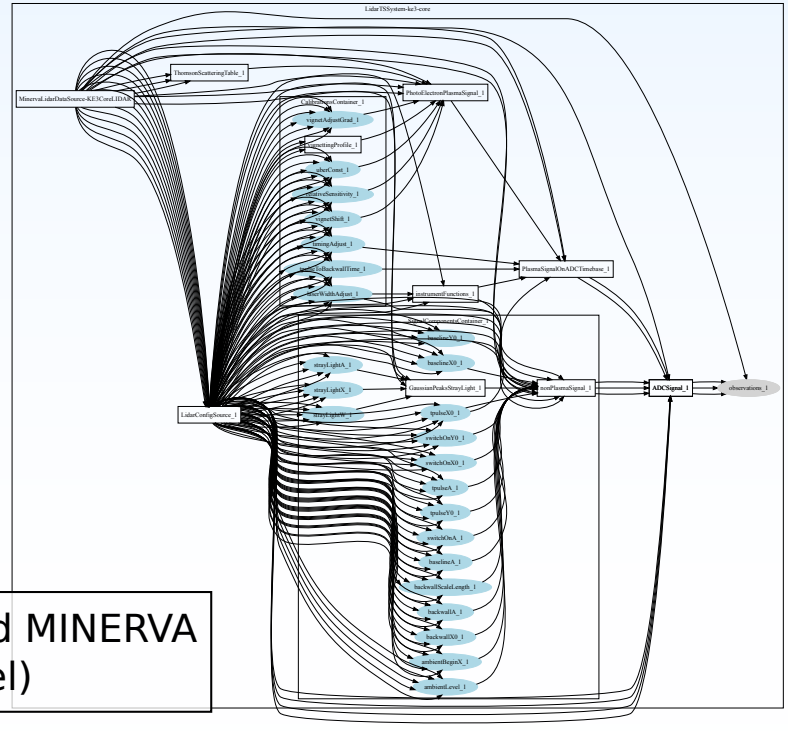

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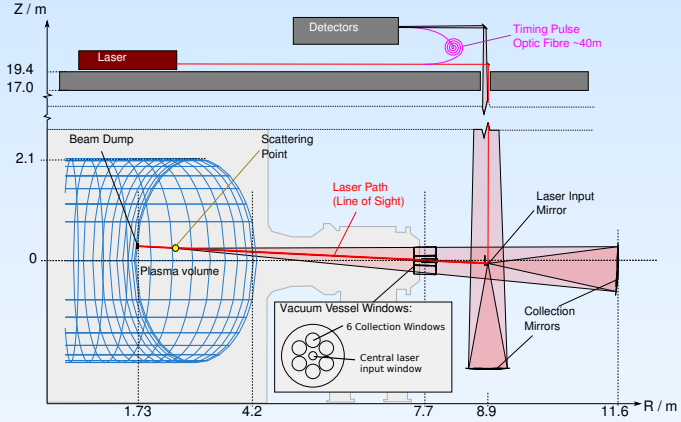

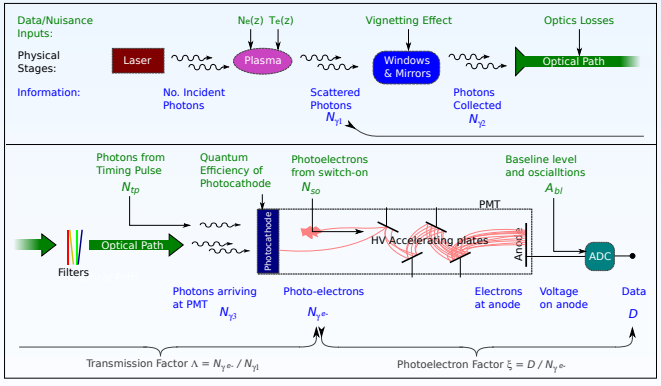

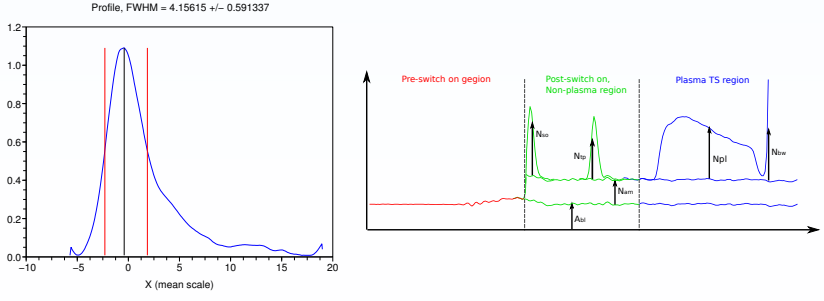

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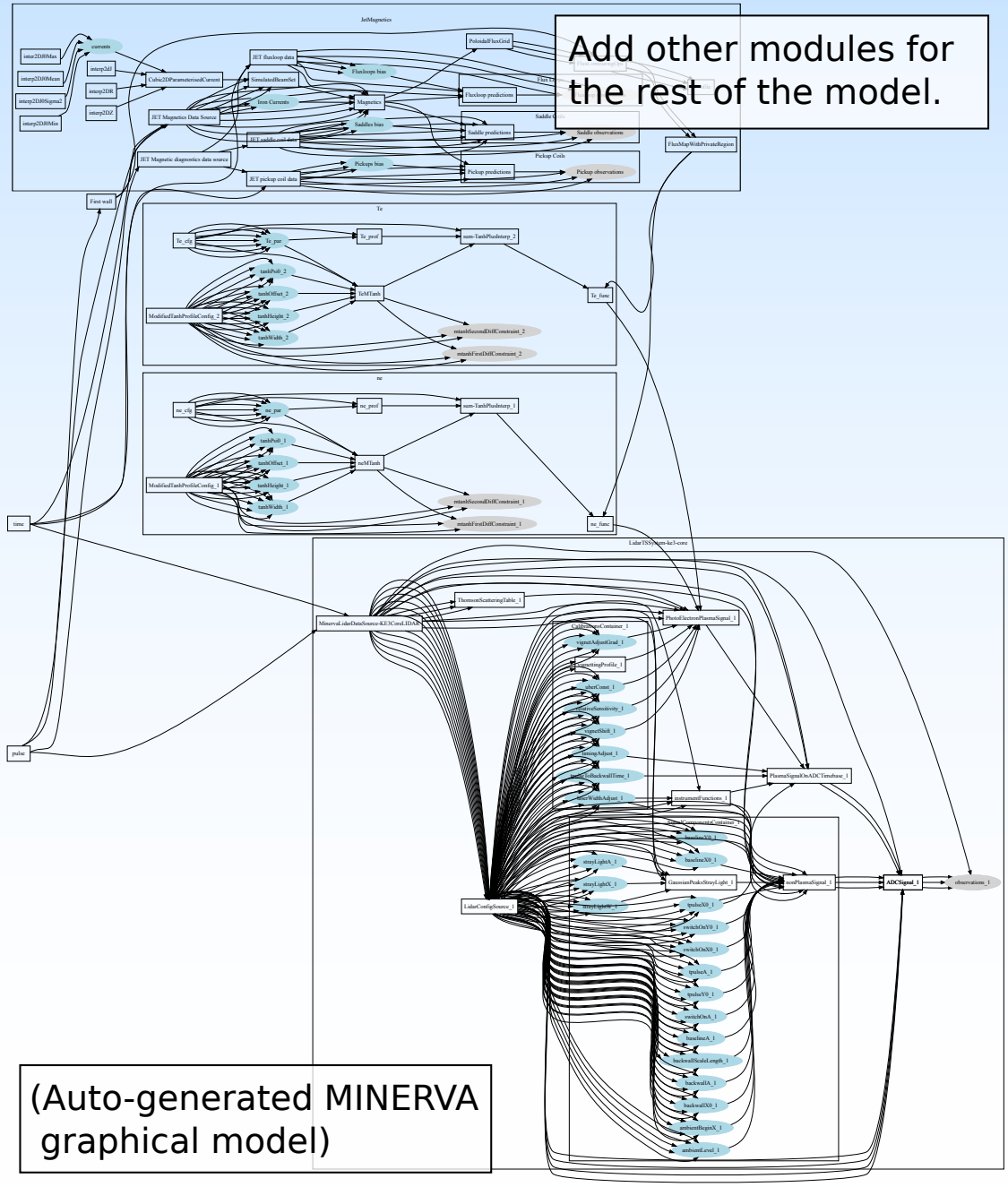
Add other modules for the rest of the model.



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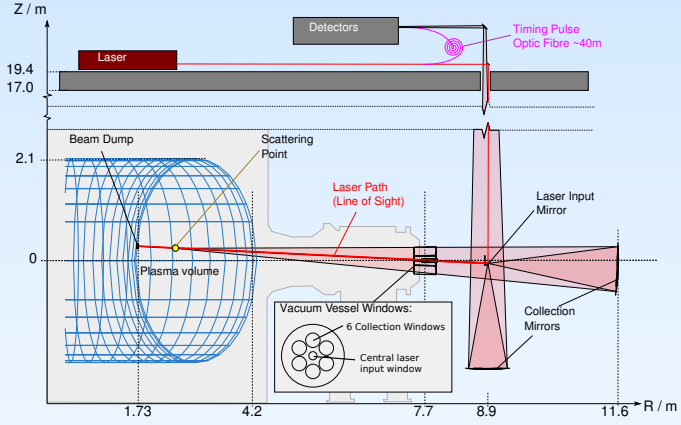

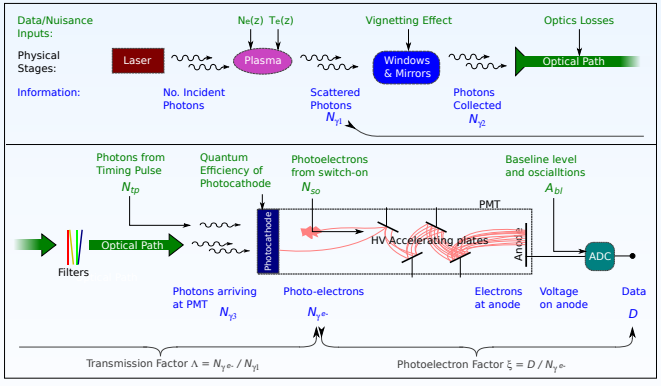

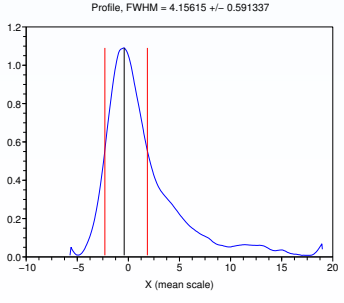

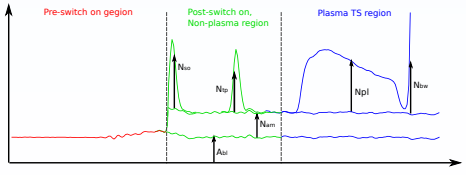

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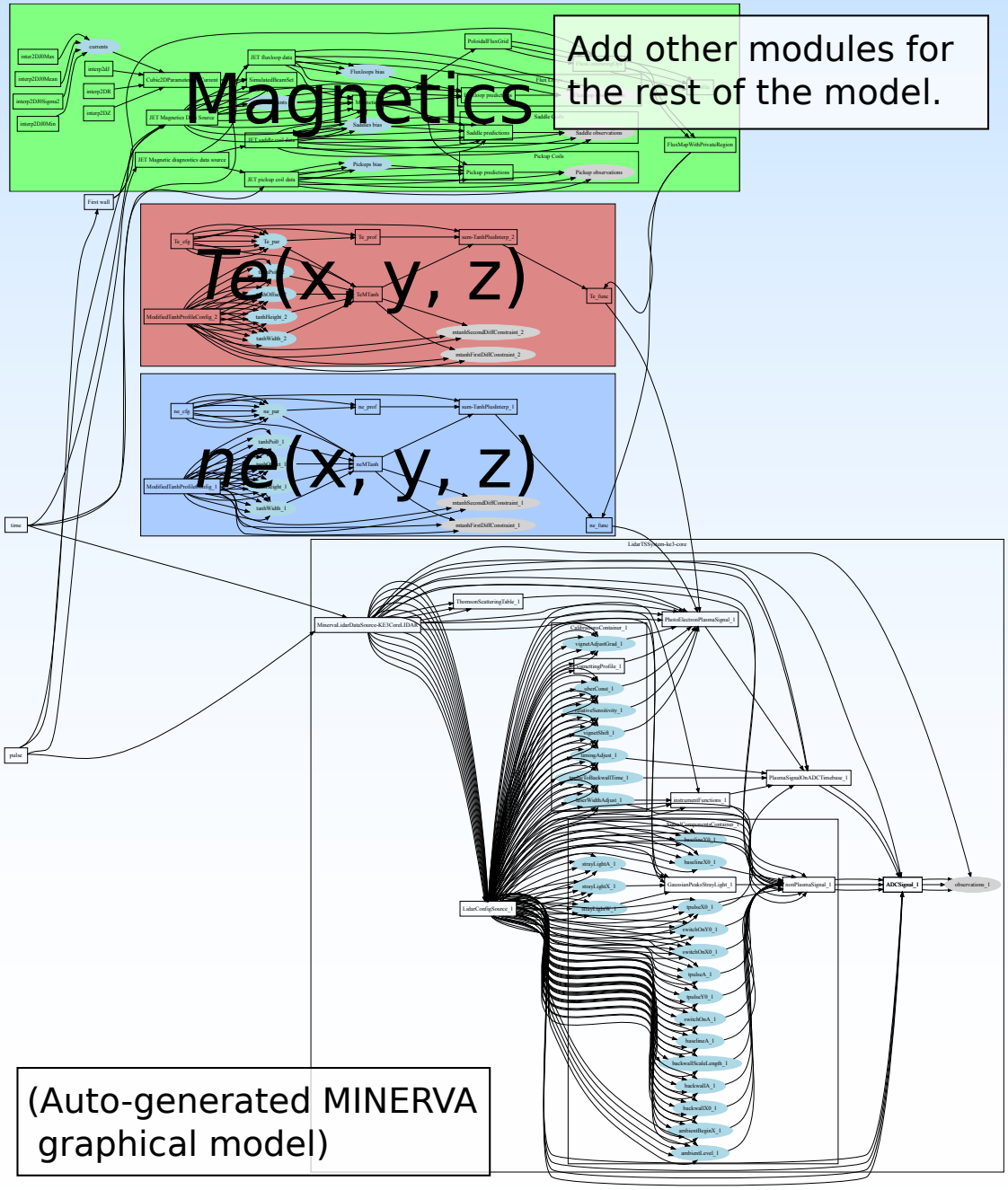

Add other modules for the rest of the model.

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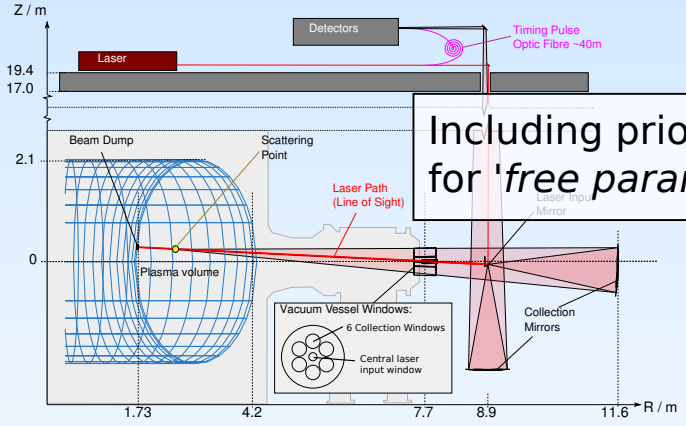
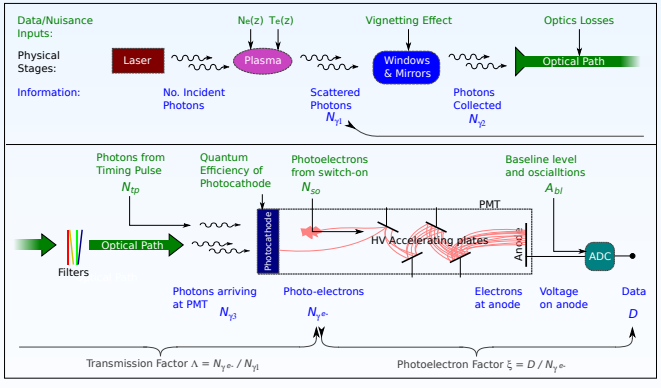


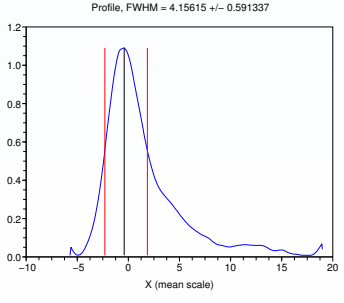
Including prior PDFs for '*free parameters*'

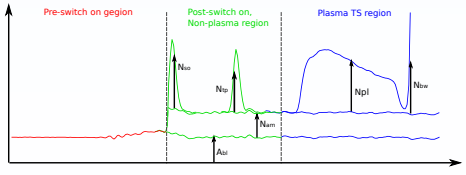
currents

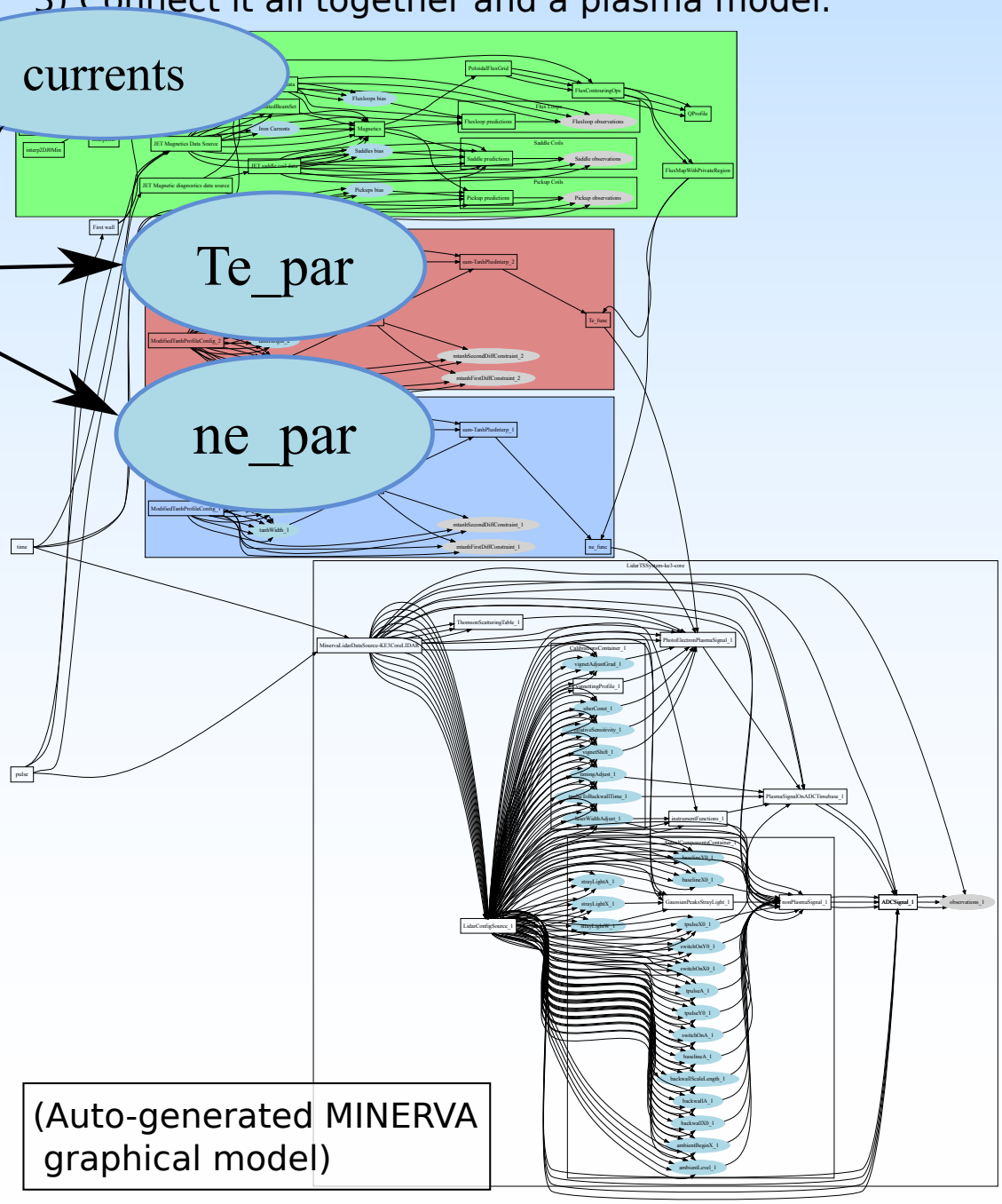
Te_par

ne_par









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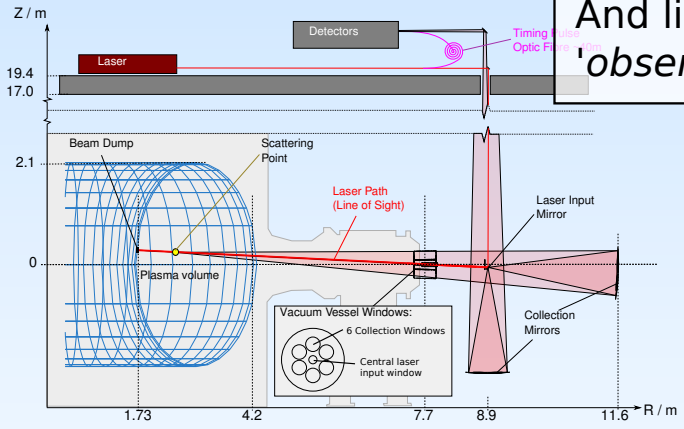
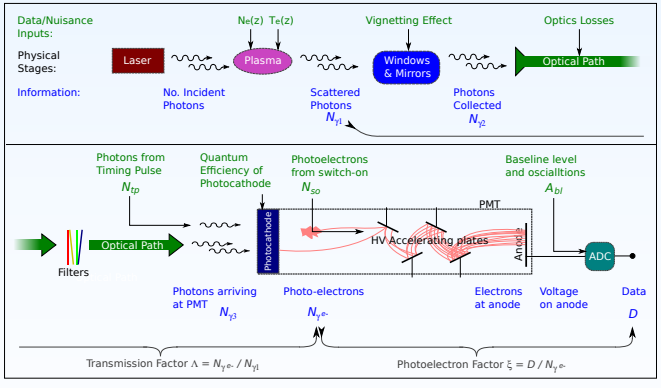
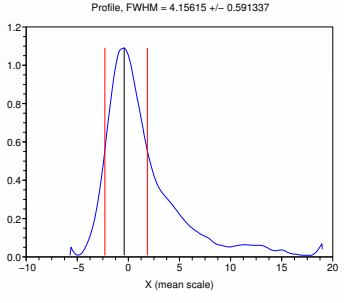
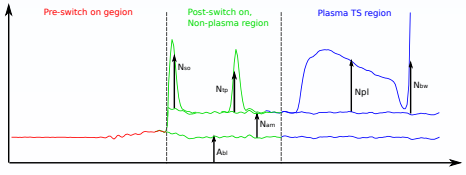
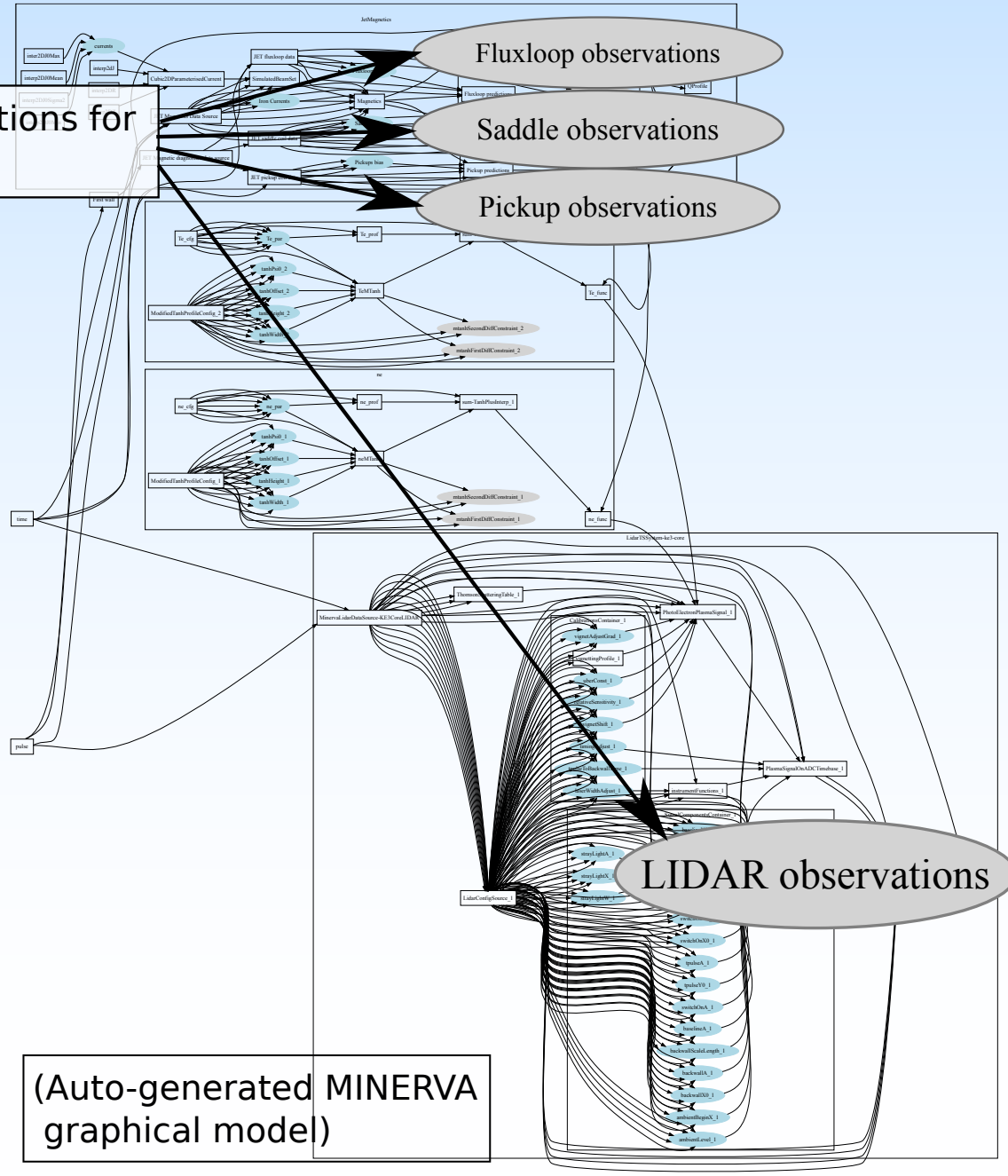


And likelihood distributions for '*observations*'.









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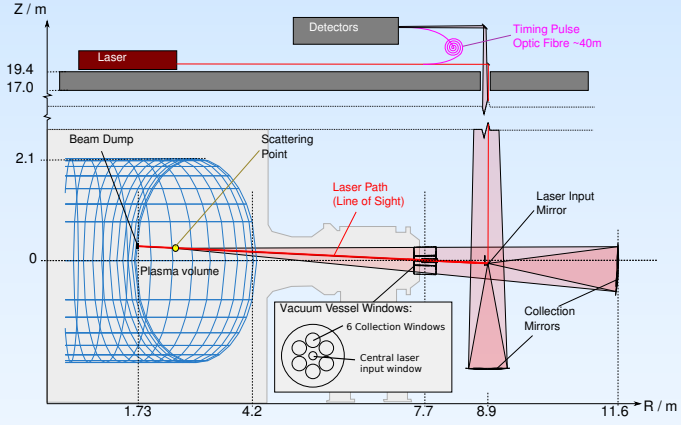

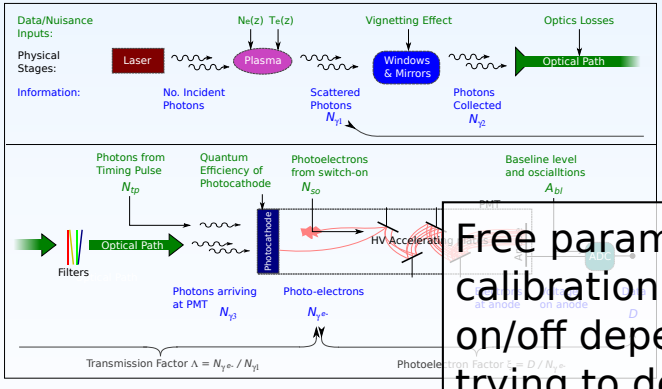

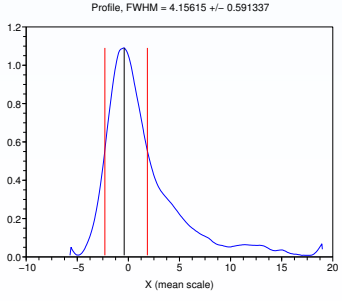

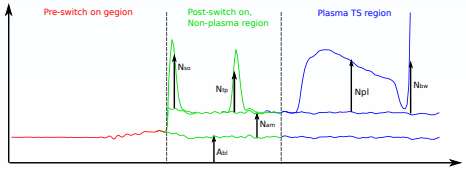

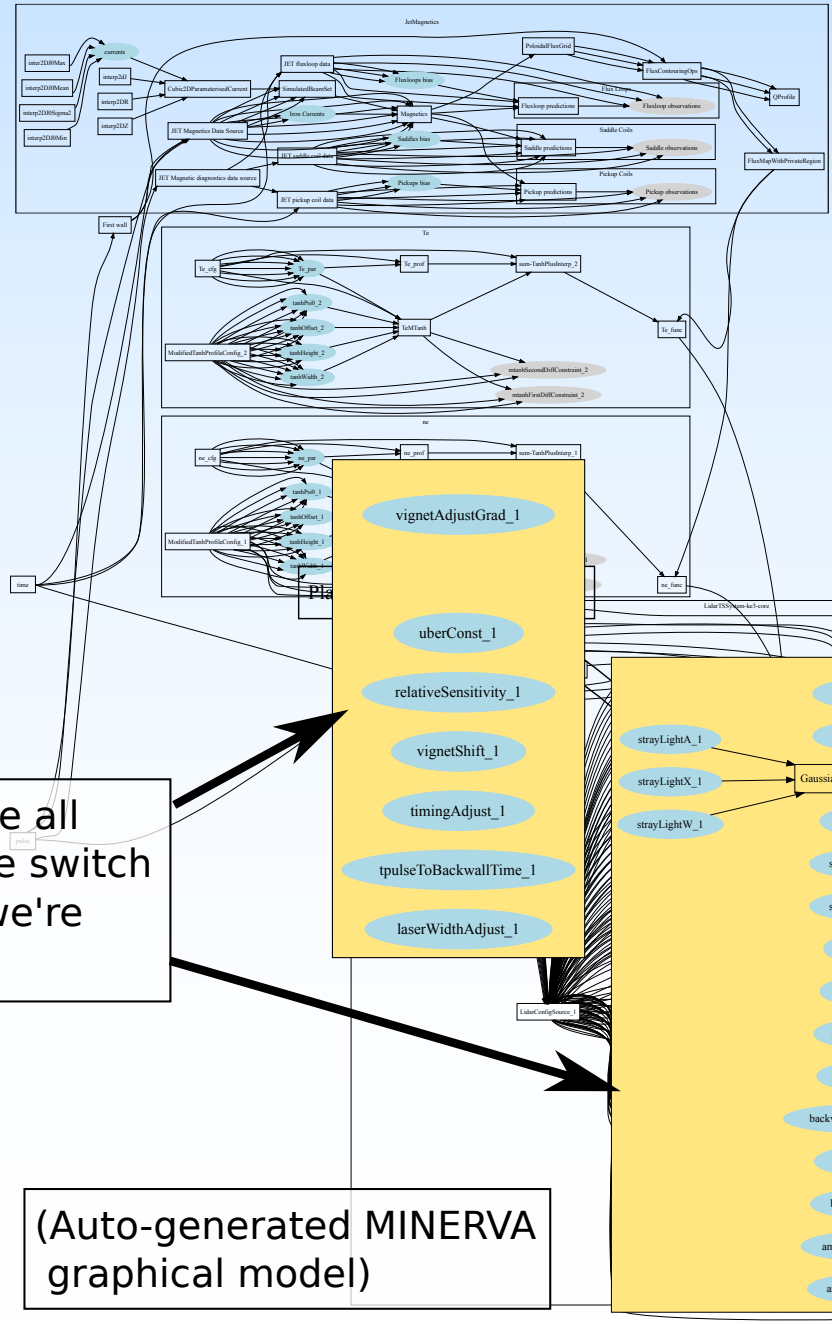

Free parameters can include all calibration values, which we switch on/off depending on what we're trying to do.

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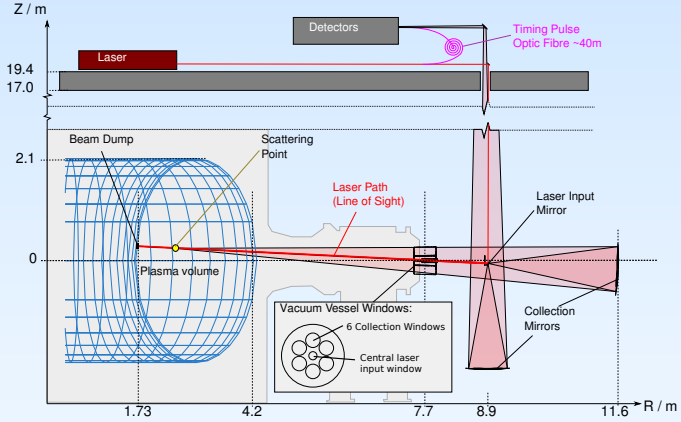

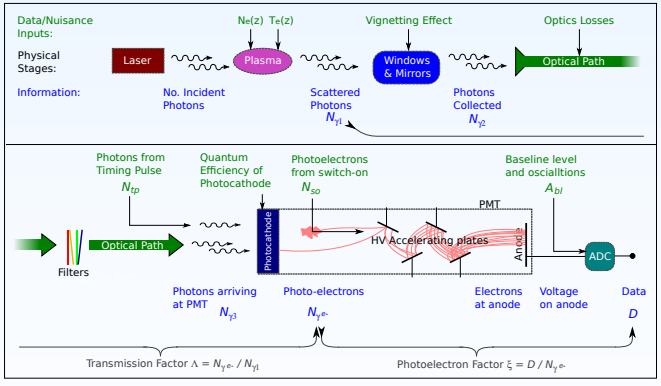

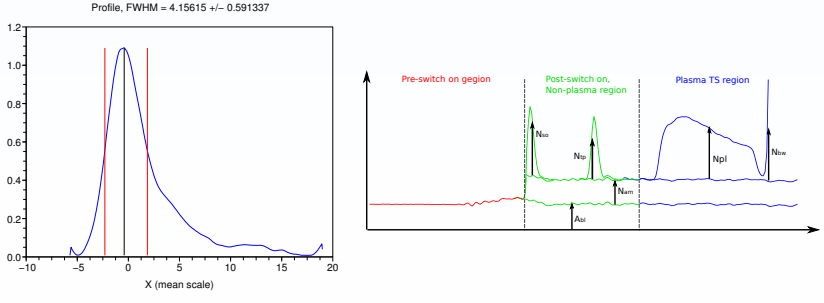

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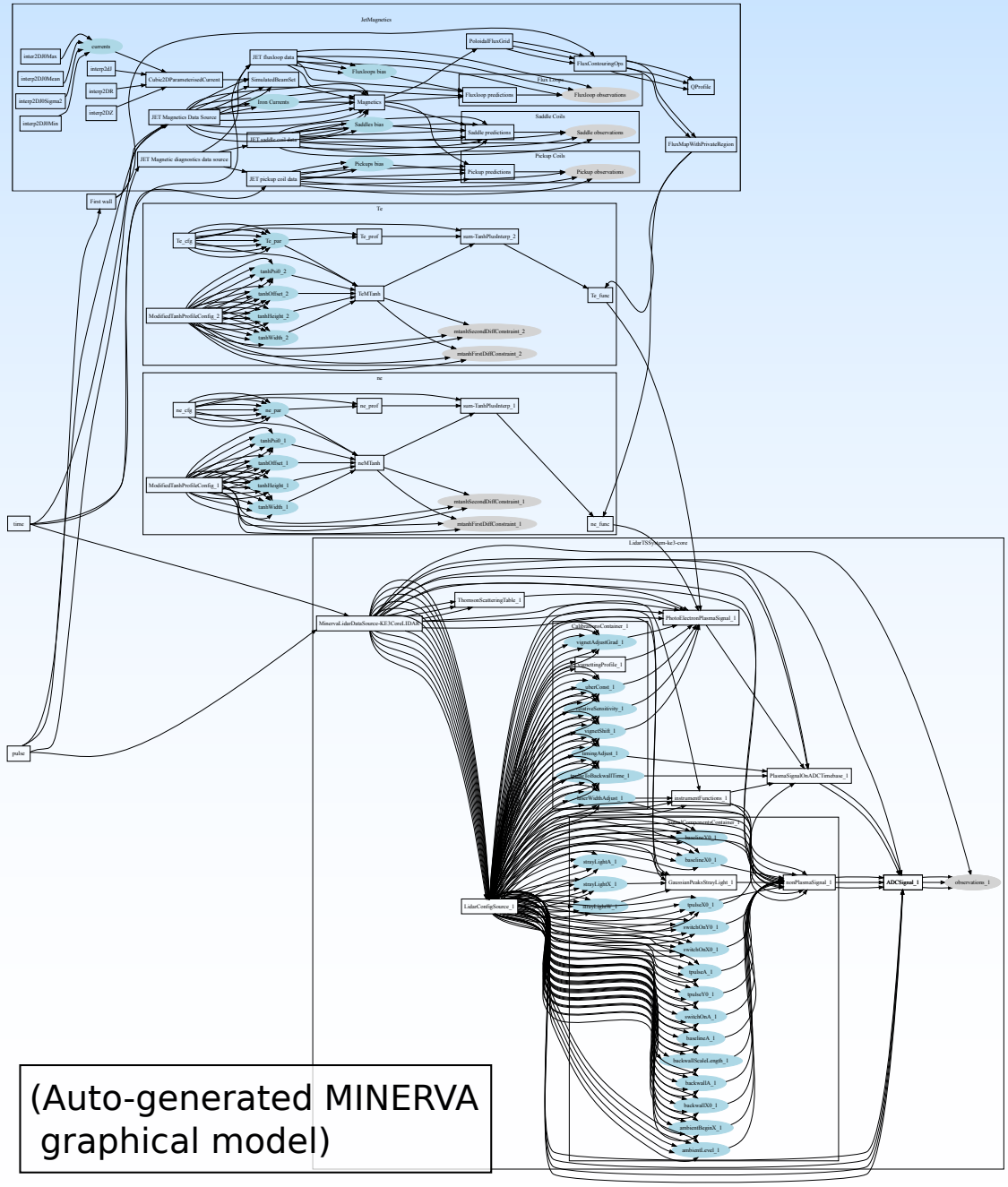

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Core + Edge LIDAR III: Early results (2008)

Early results:

Core LIDAR + Interferometry on EFIT ψ_N.

Weak priors on all calibration parameters except relative sensitivities (T_e magnitude calibration).

Most calibrations are determined by consistency and data (either LIDAR or Interferometry).

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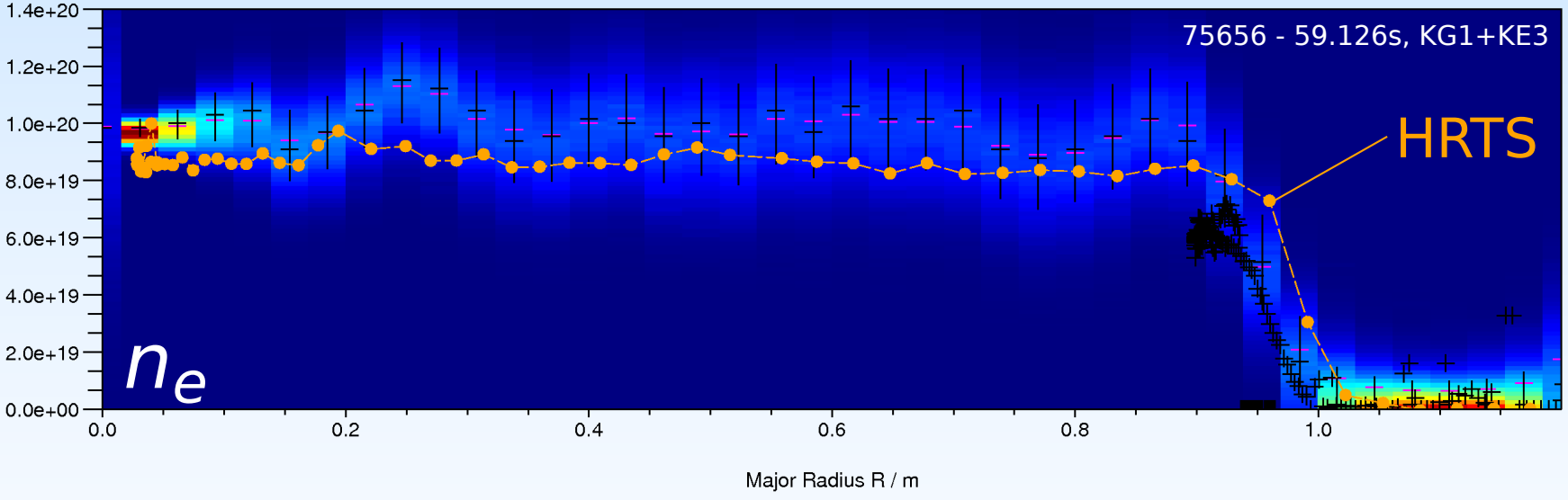

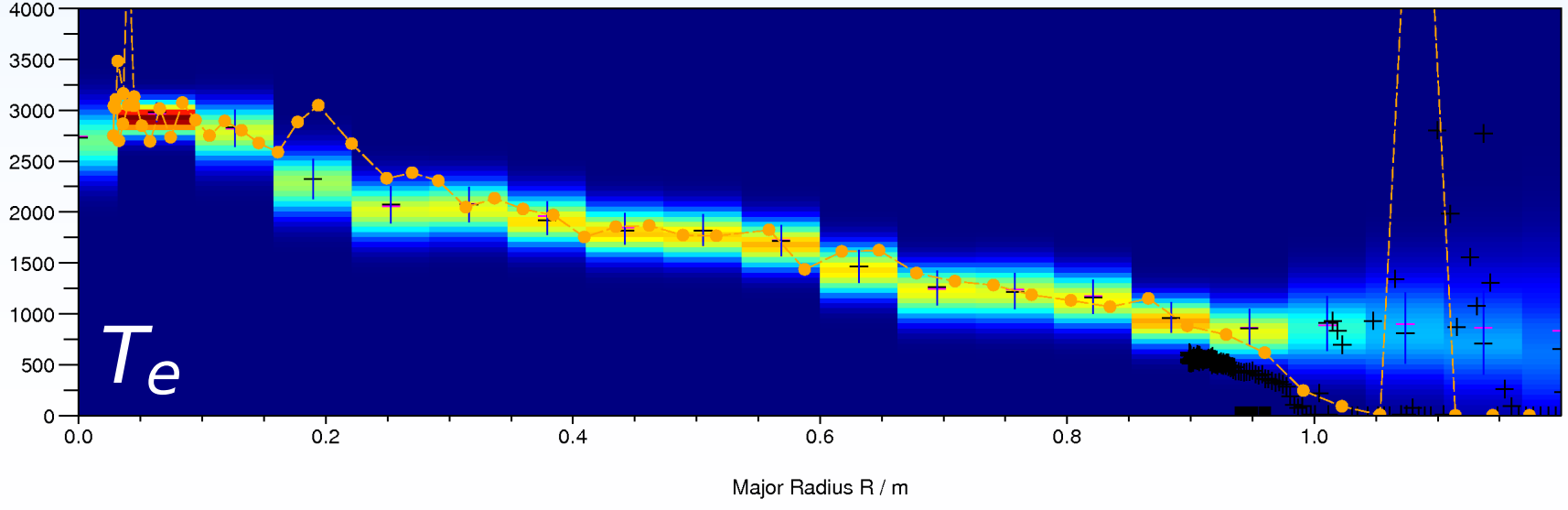

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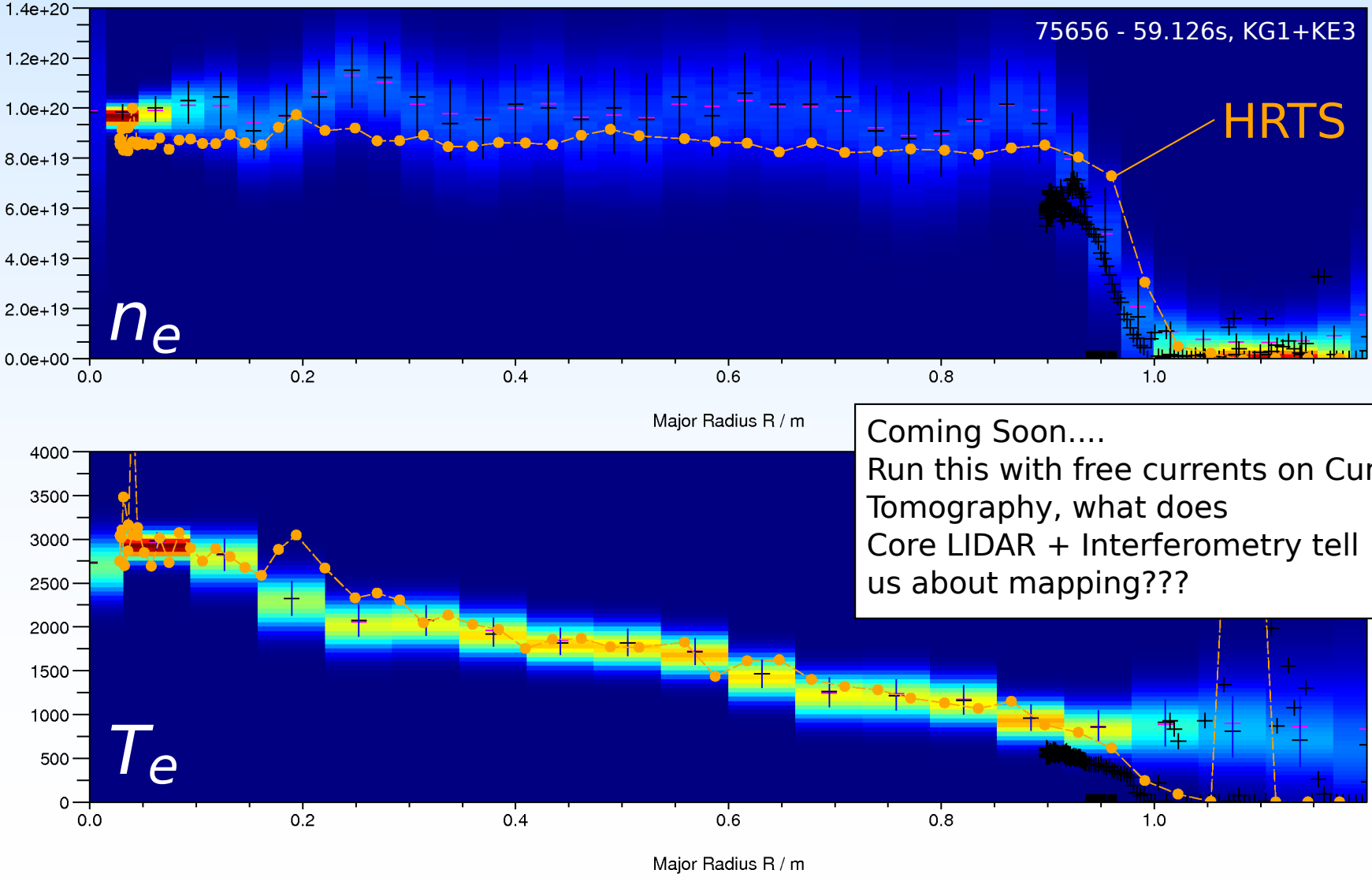

Coming Soon....
Run this with free currents on Current Tomography, what does Core LIDAR + Interferometry tell us about mapping???

Core + Edge LIDAR IV: Pedestal Information from core LIDAR.

Core LIDAR has ~12cm convolution and data points for every 3cm - it will never completely 'resolve' the pedestal. But, can it tell us anything, if we help it out a bit?...

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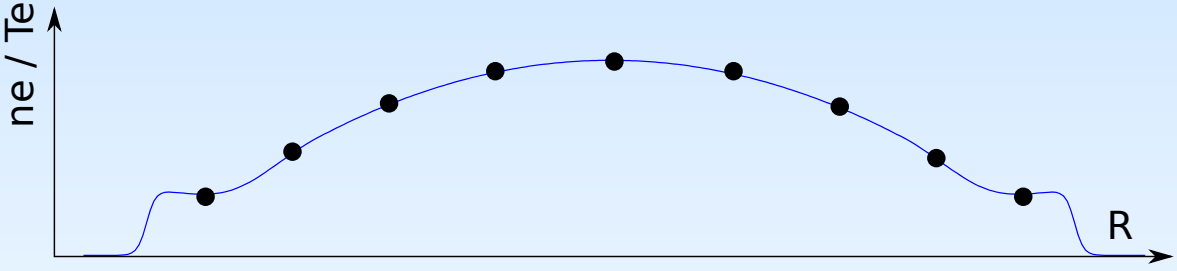

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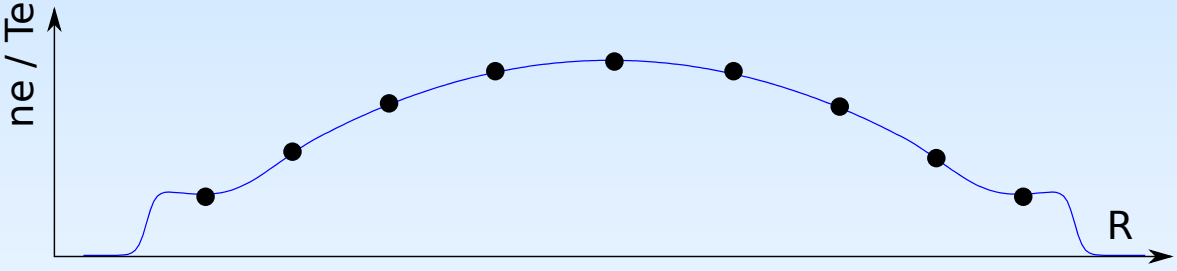

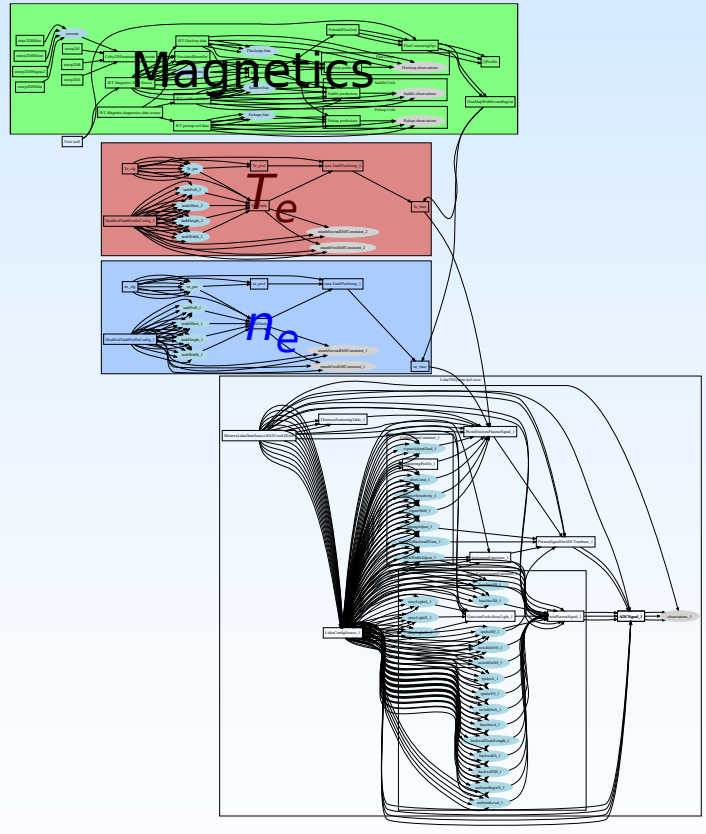

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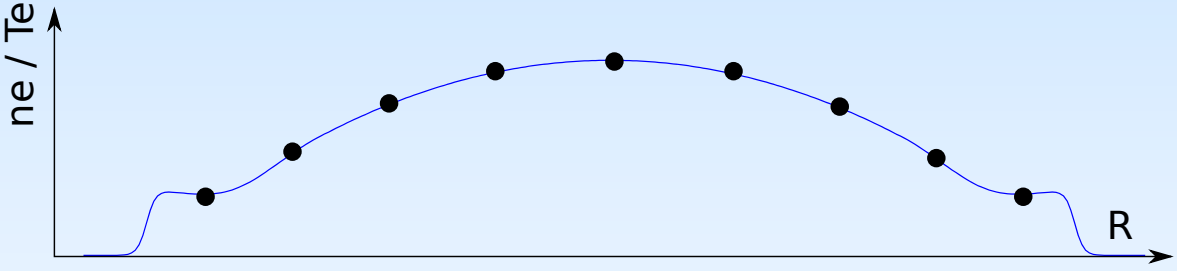

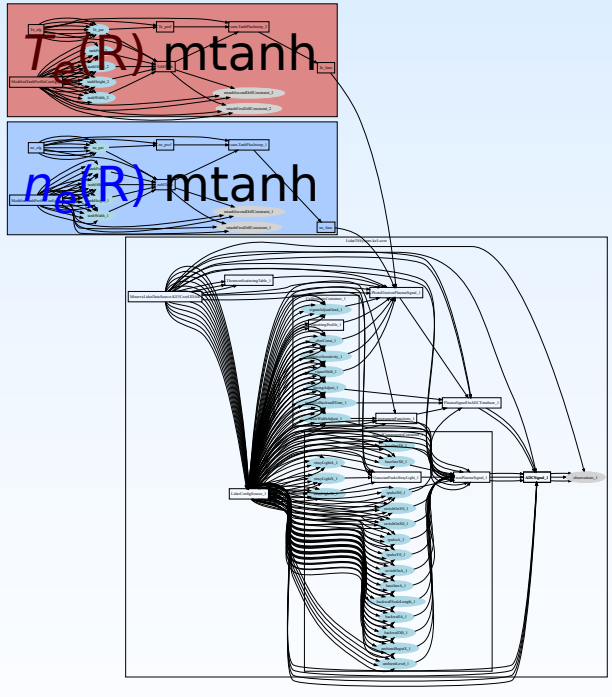

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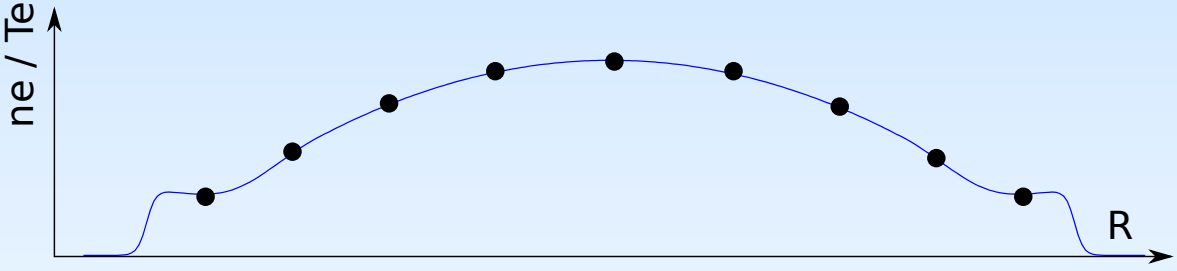
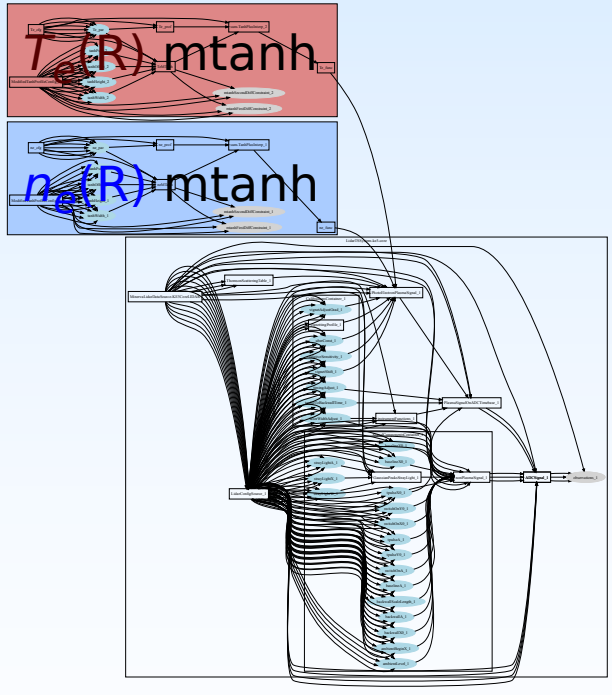
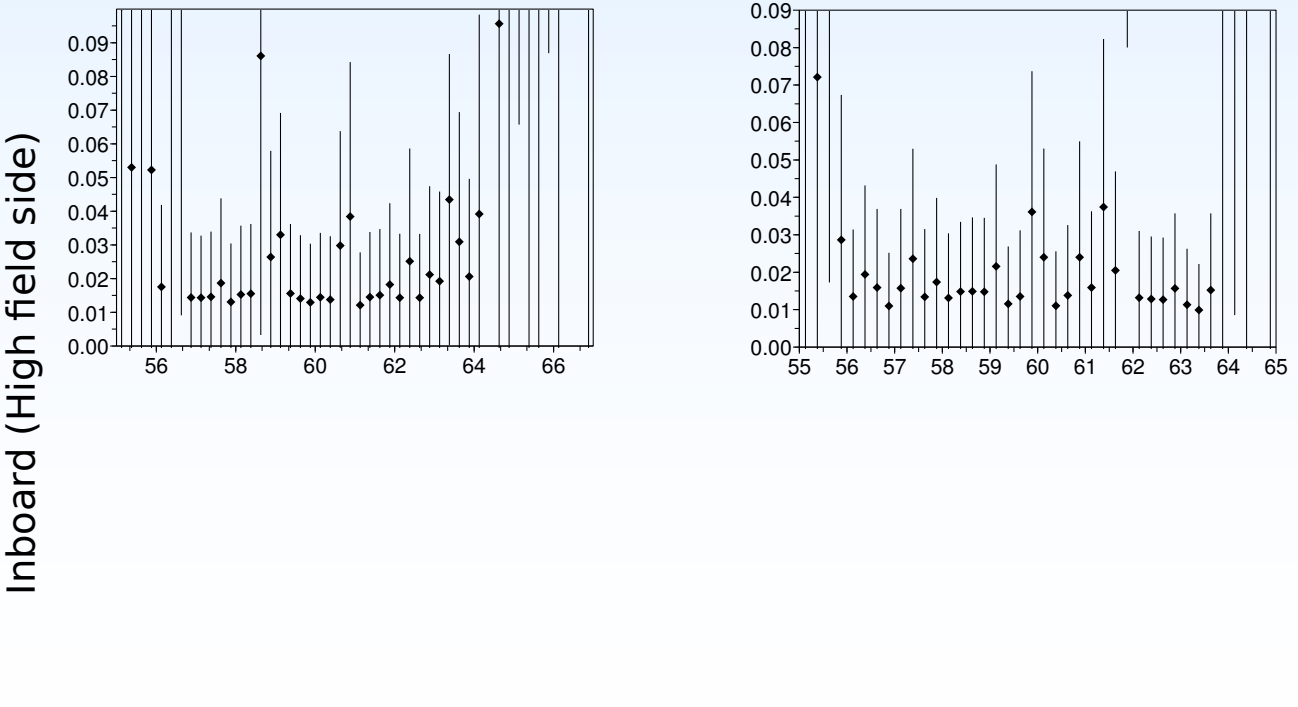




Run for a whole shot:



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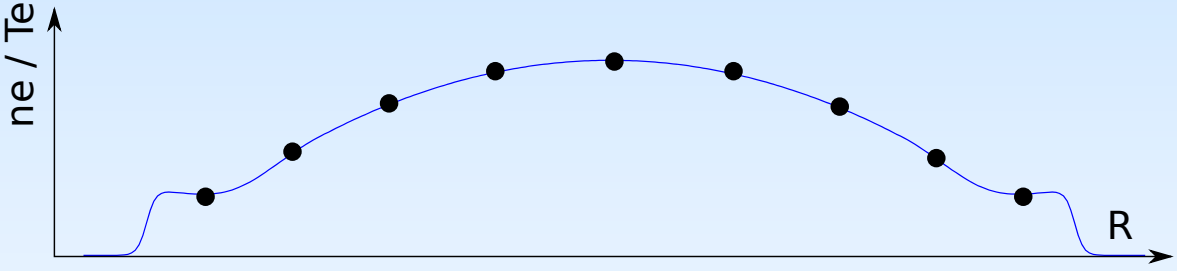

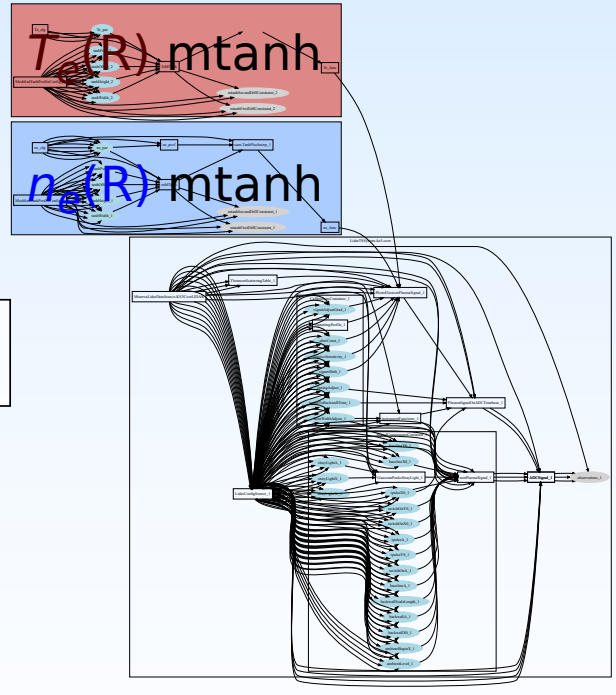

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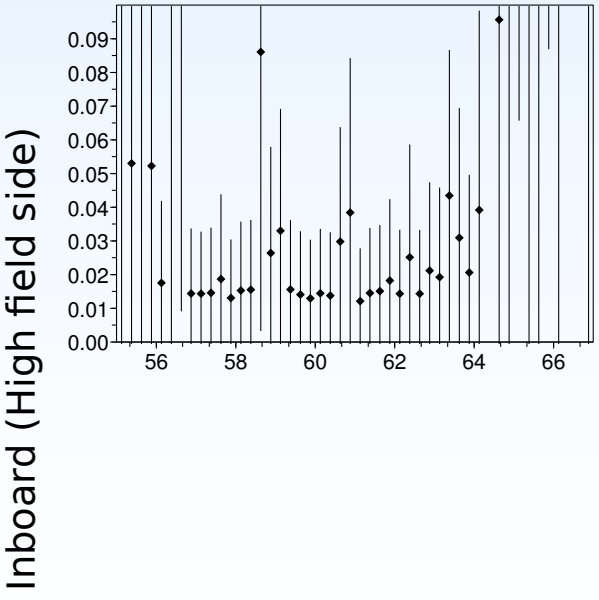

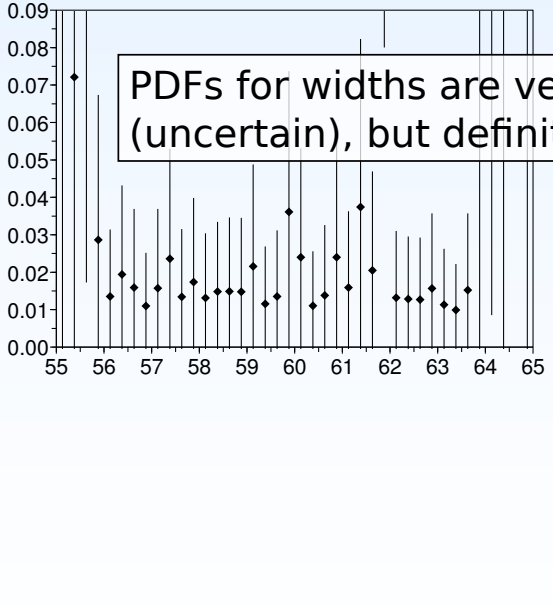

PDFs for widths are very wide (uncertain), but definitely < 5cm.

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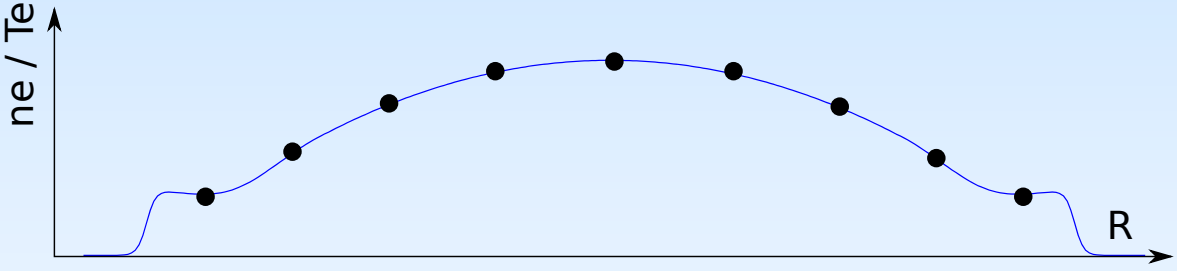

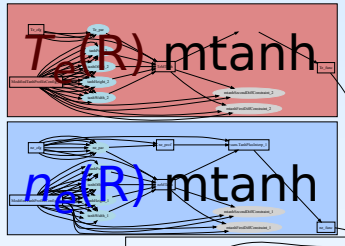

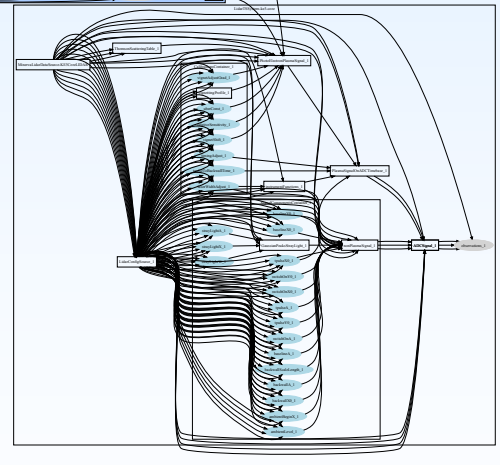

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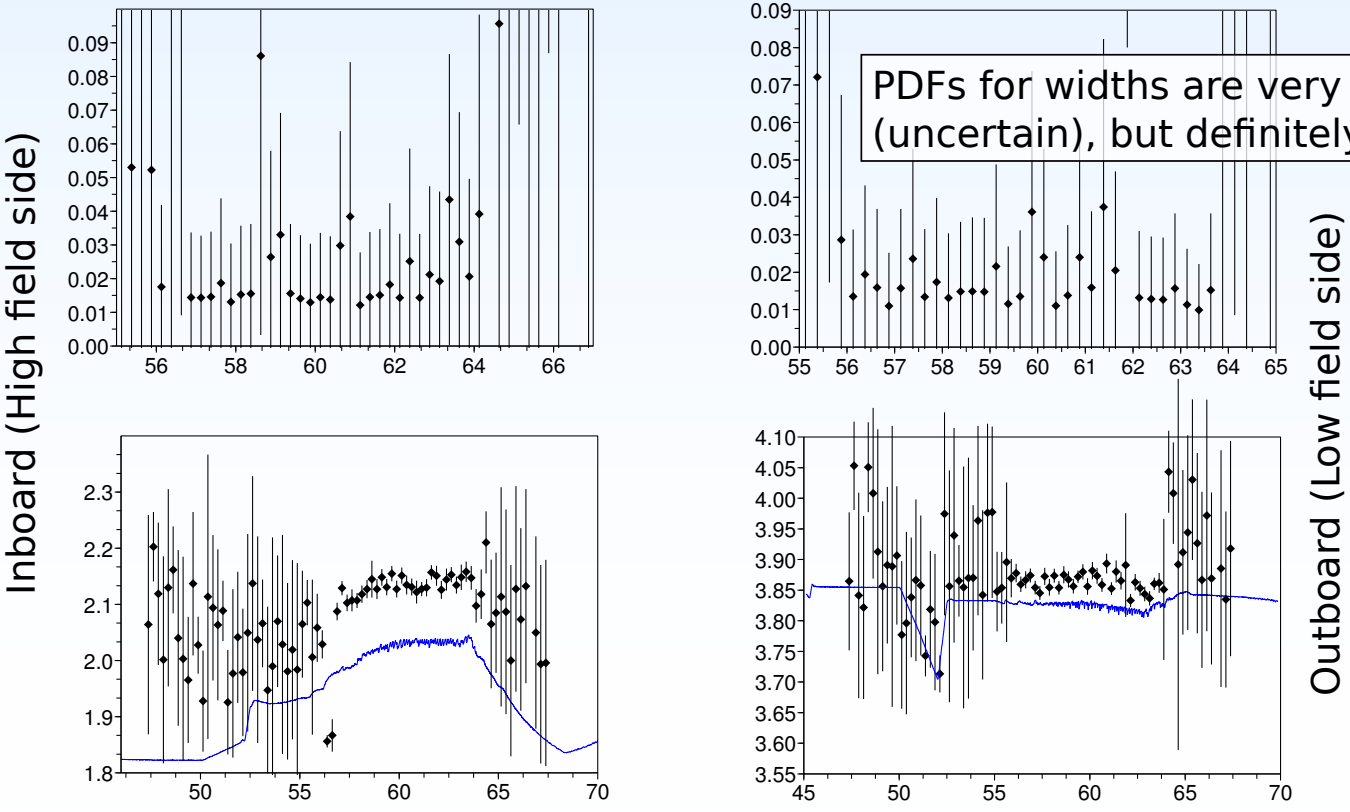

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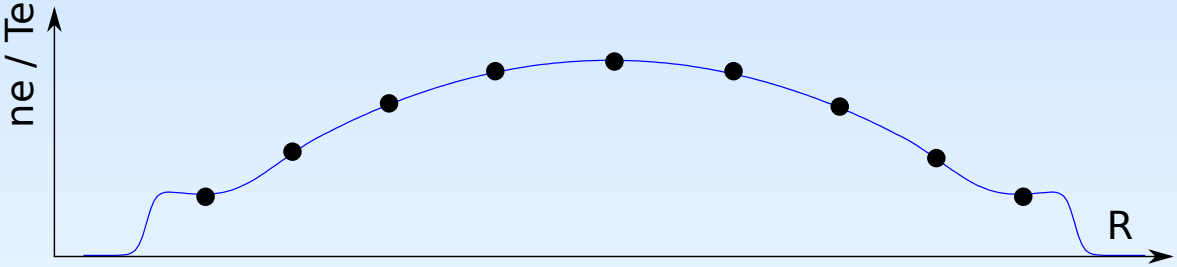

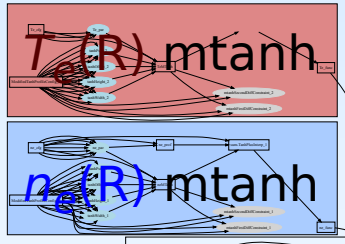

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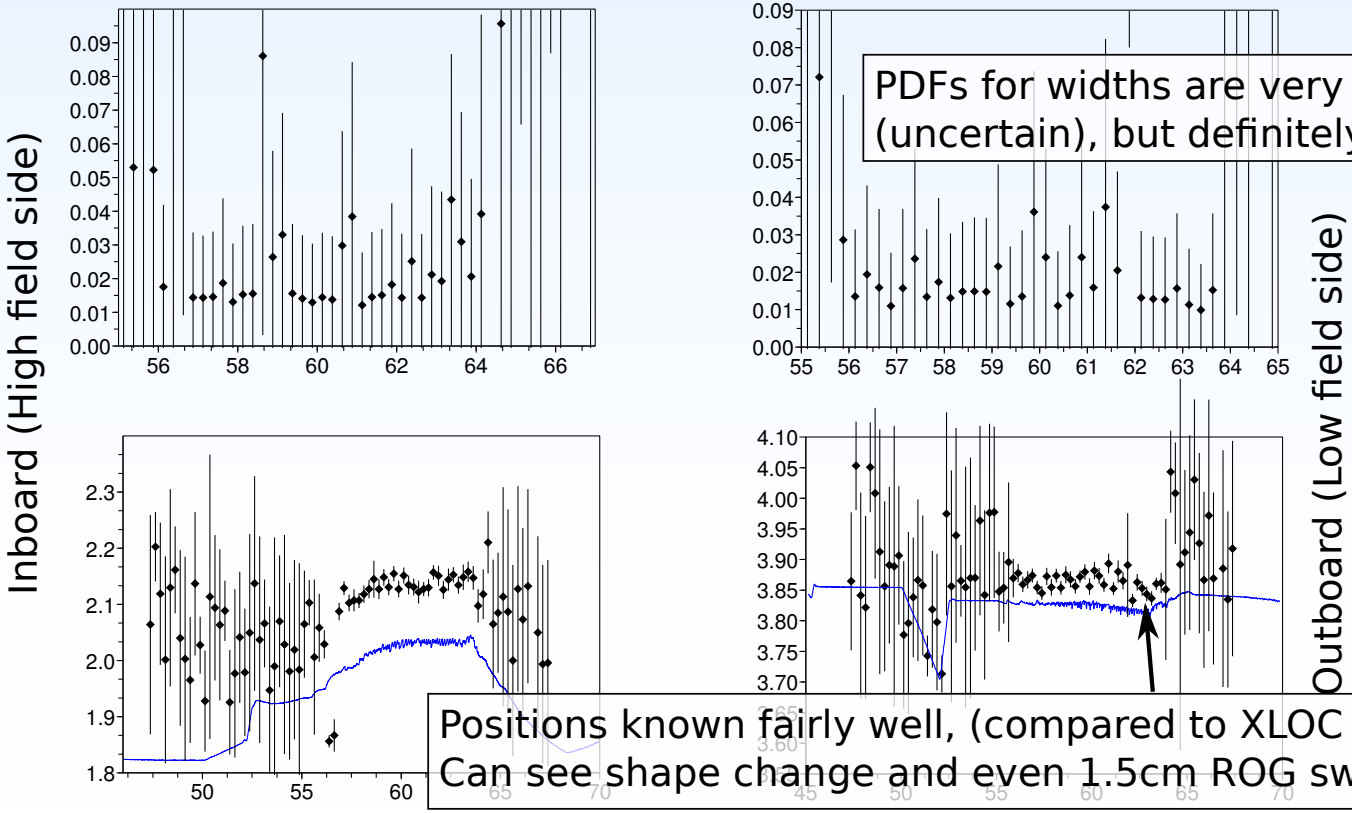

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Positions known fairly well, (compared to XLOC here)
Can see shape change and even 1.5cm ROG sweep through average.

Core + Edge LIDAR V: Add edge LIDAR.

As with core LIDAR, calibrations (**position**, n_e **magnitude** etc) all have uncertainty (some large).

n_e

T_e

Core + Edge LIDAR V: Add edge LIDAR.

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- Photoelectron calibration implies **noise level** much less than observed - recalculated from noise on data.
- Relative sensitivities (T_e **calibration**) seem to disagree with other diagnostics, so give wide prior.
- **Stray light** a **BIG** problem for low *ne* shots - aquire from dry-runs.

n_e

T_e

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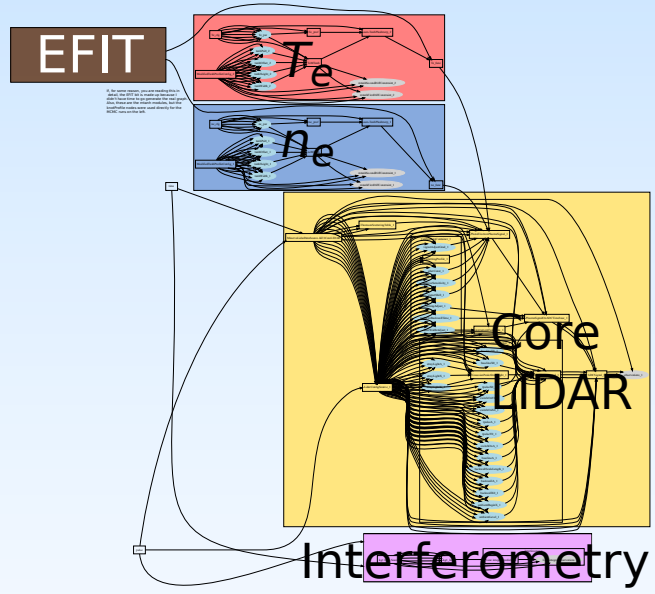

n_e

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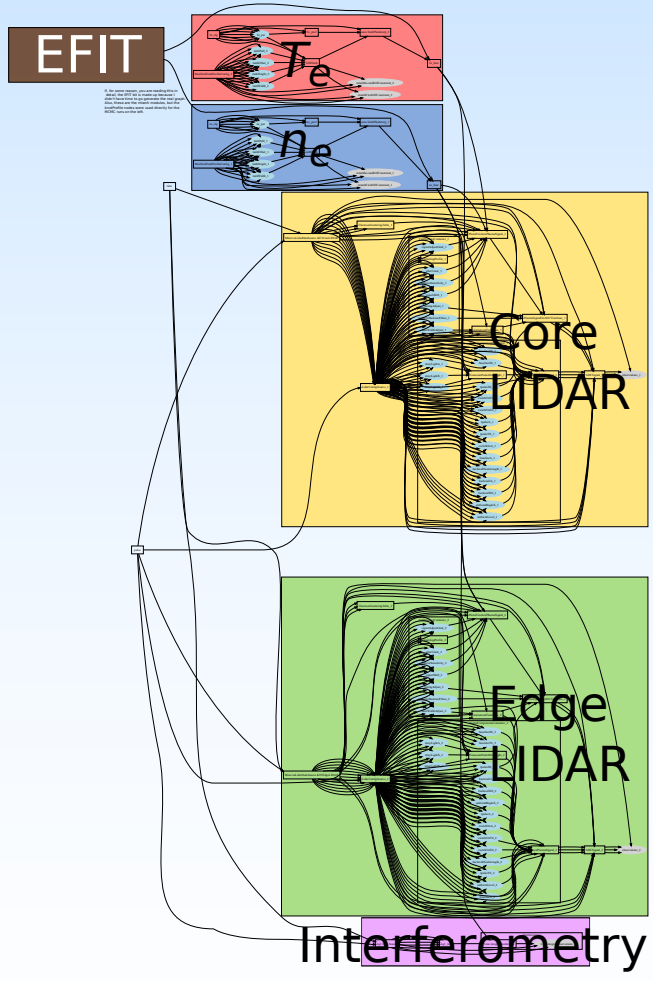

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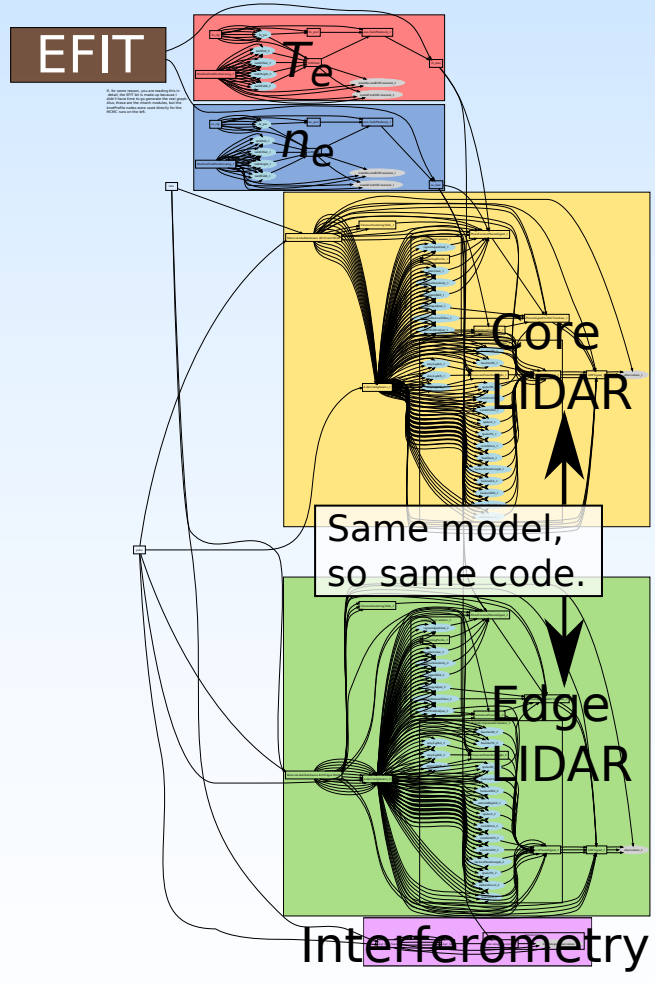

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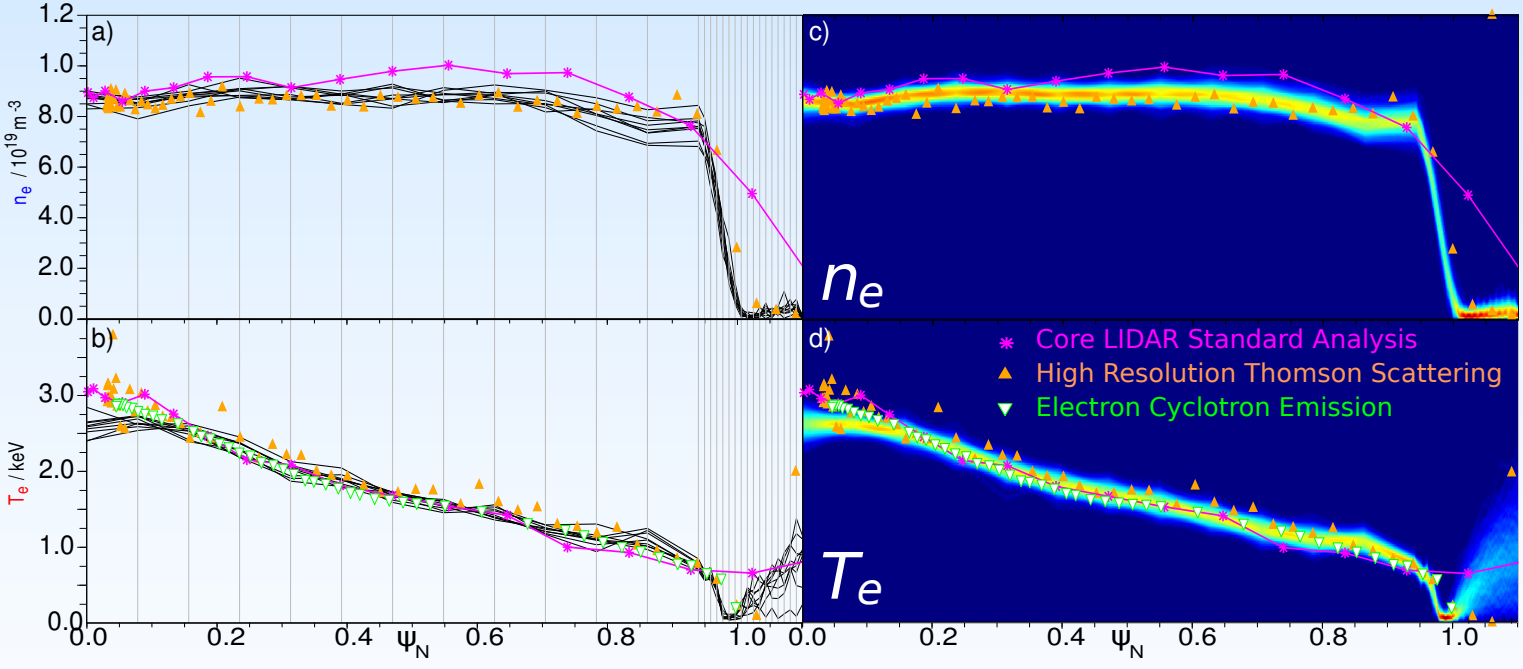

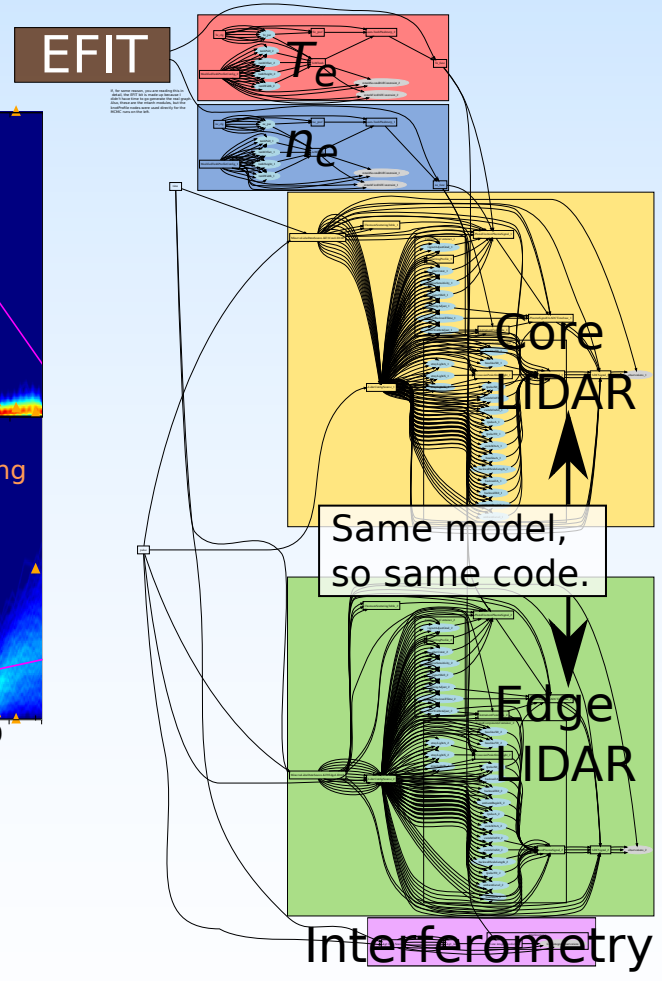

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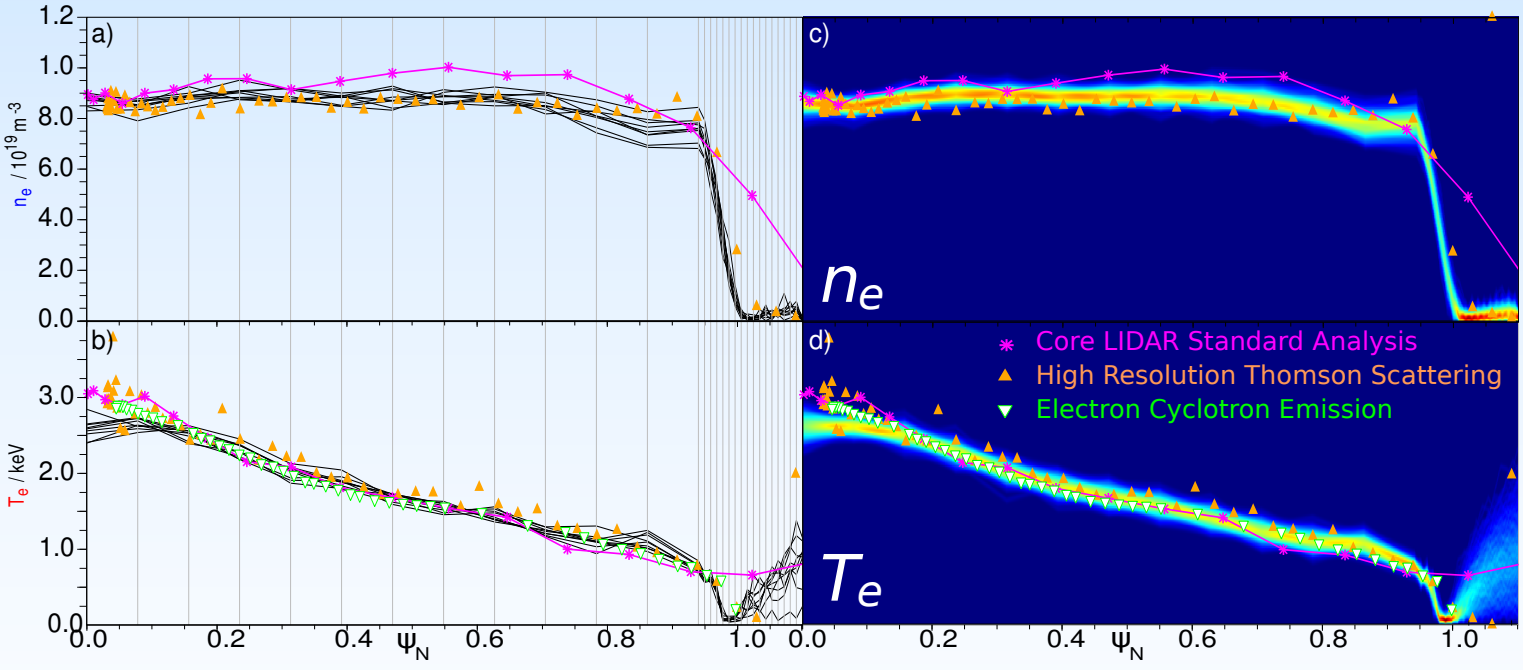

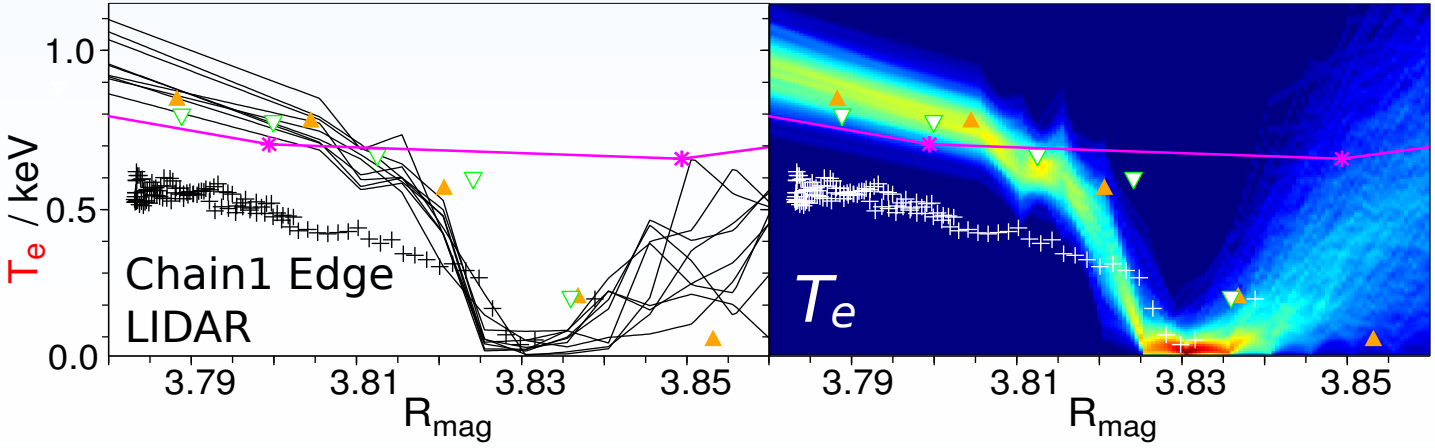

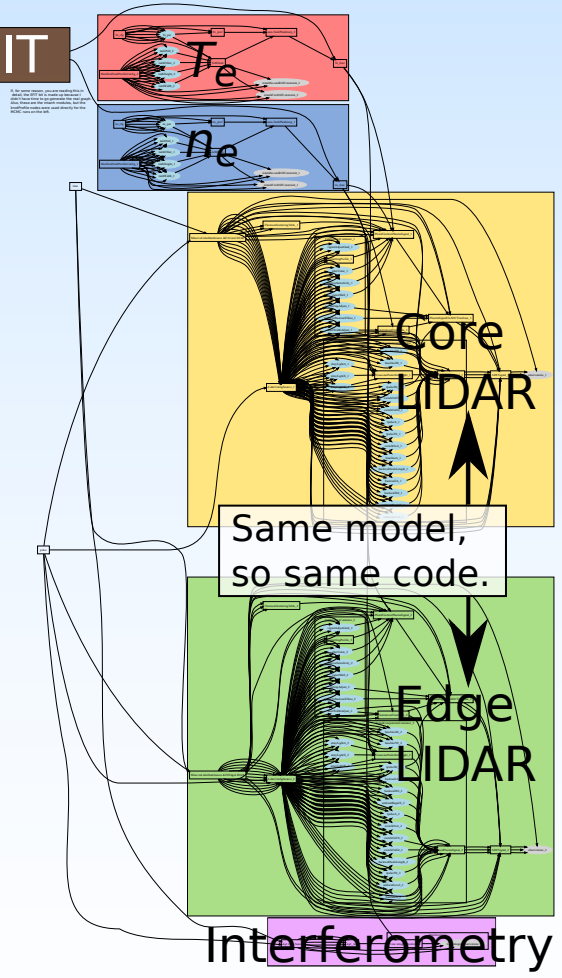

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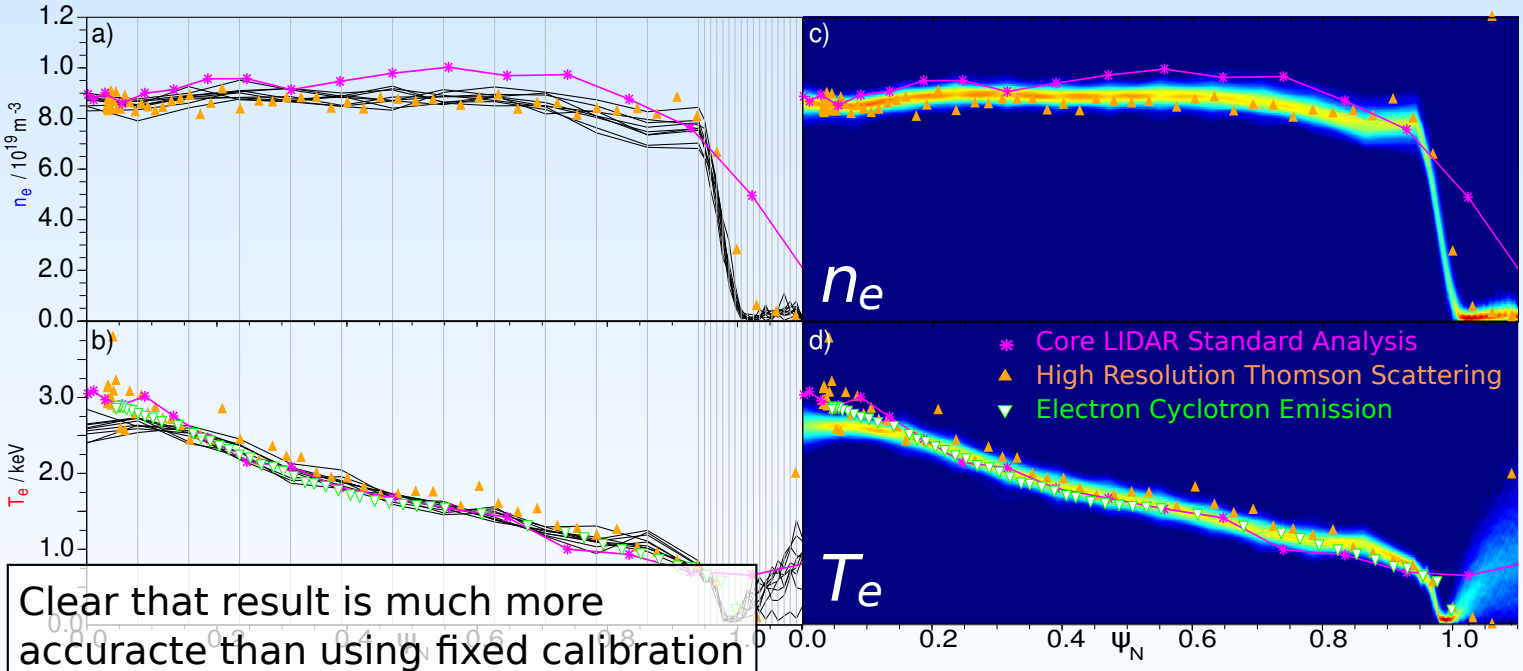

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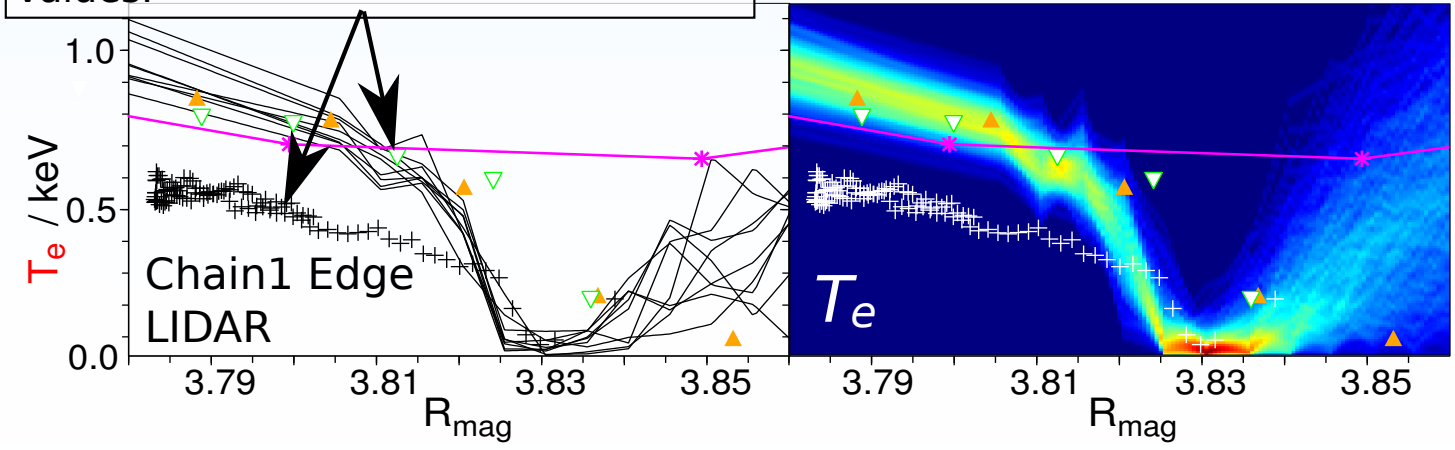

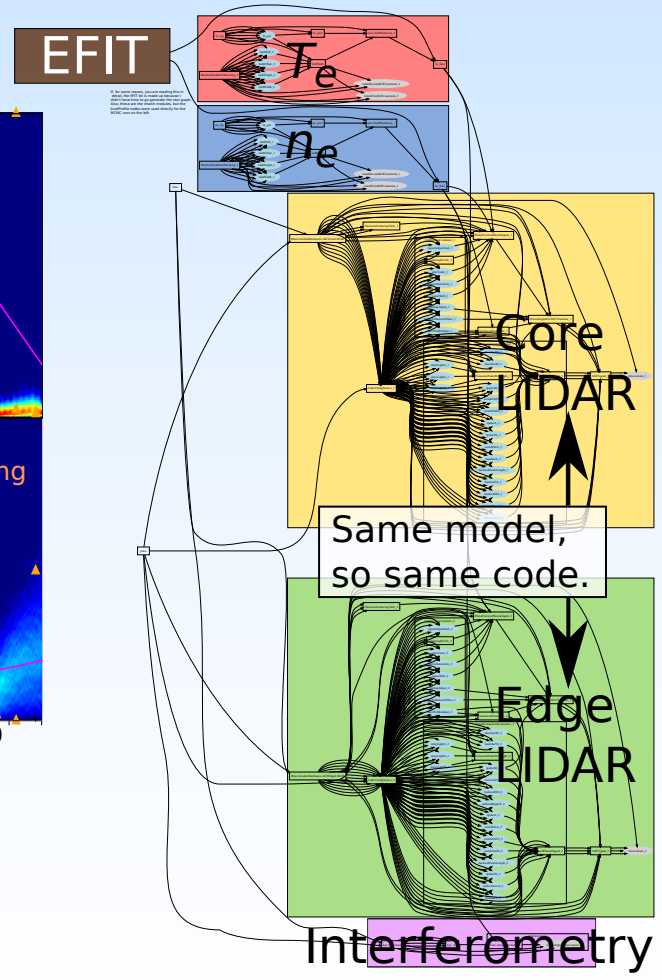

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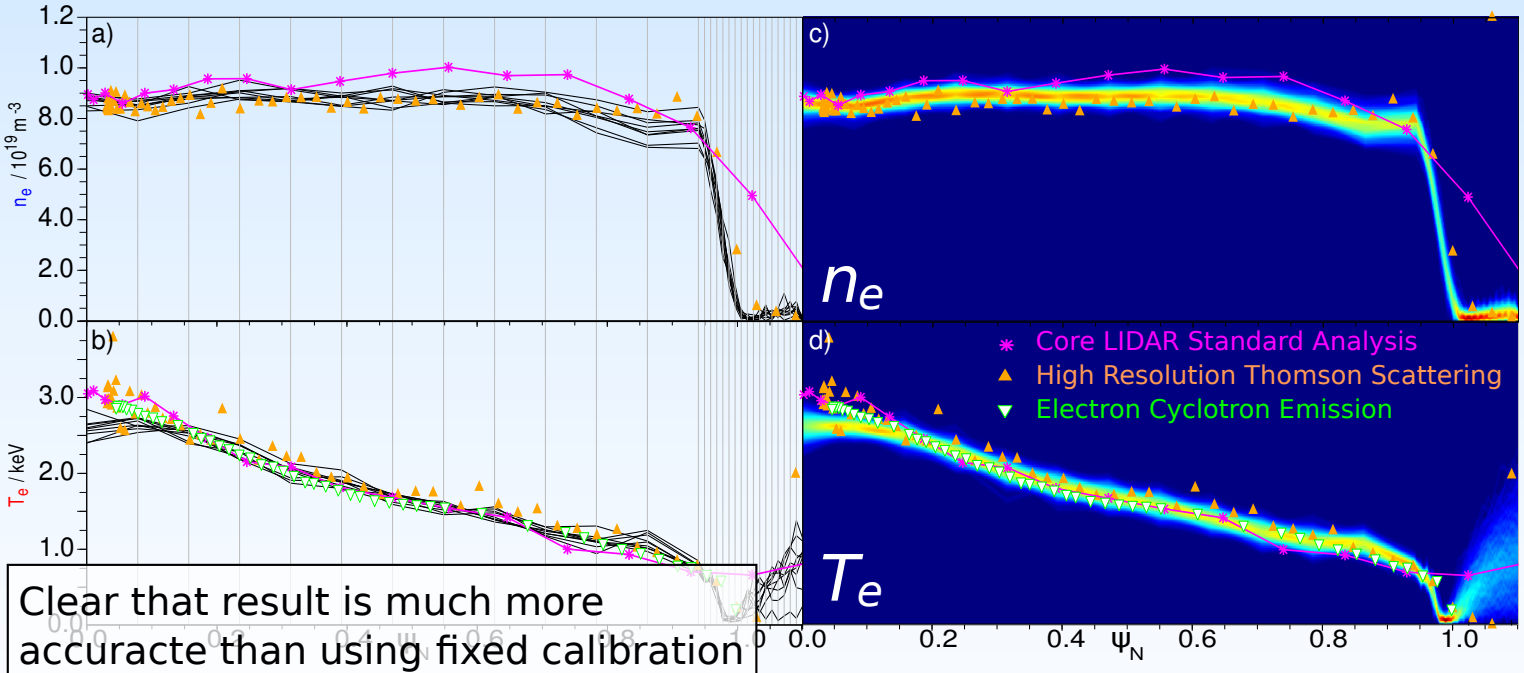

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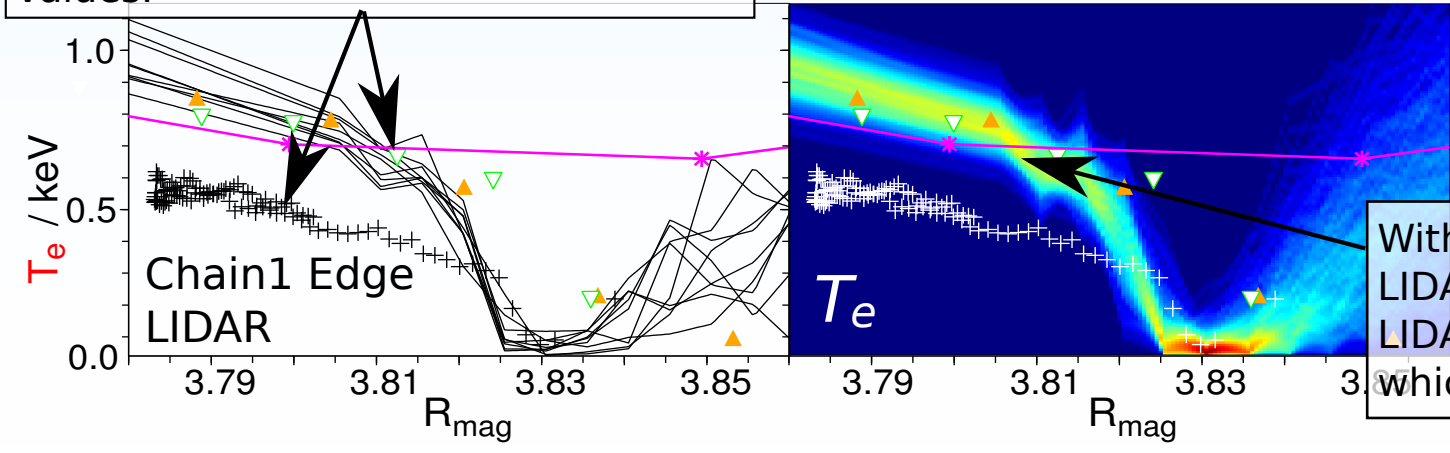

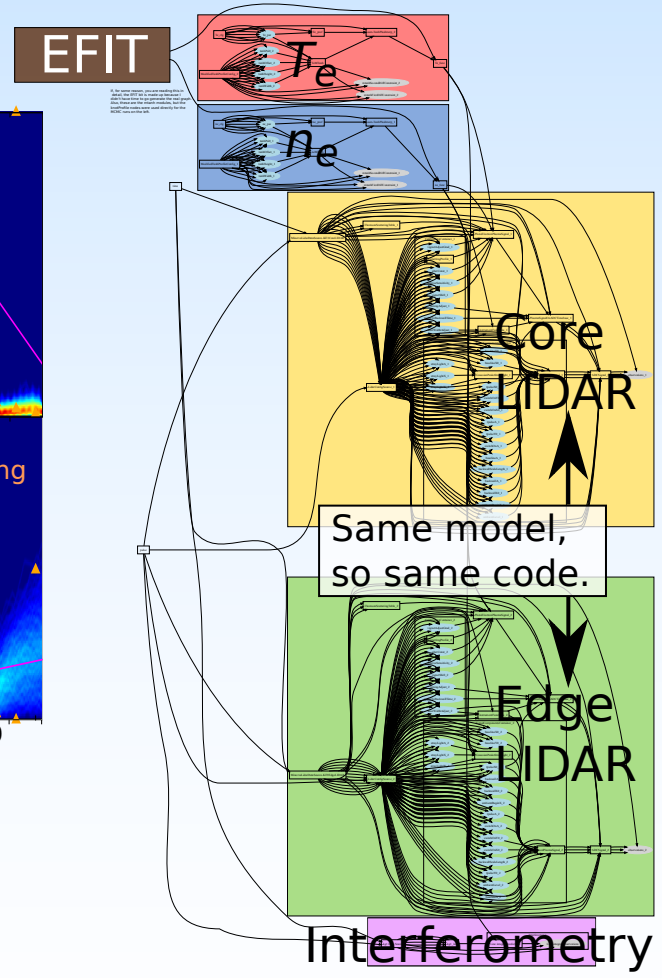

With completely free calibration, edge LIDAR provides shape with which Core LIDAR can give accurate *T_e* ped height which feeds back to Edge LIDAR

Core + Edge LIDAR VI: Calibrations Inference.

Find posterior maximum (best fit) for mtanh parametrised $n_e(\psi_N)$ and $T_e(\psi_N)$ with Core+Edge LIDAR with completely free edge LIDAR T_e calibrations. Look at inferred calibration for C25-present:

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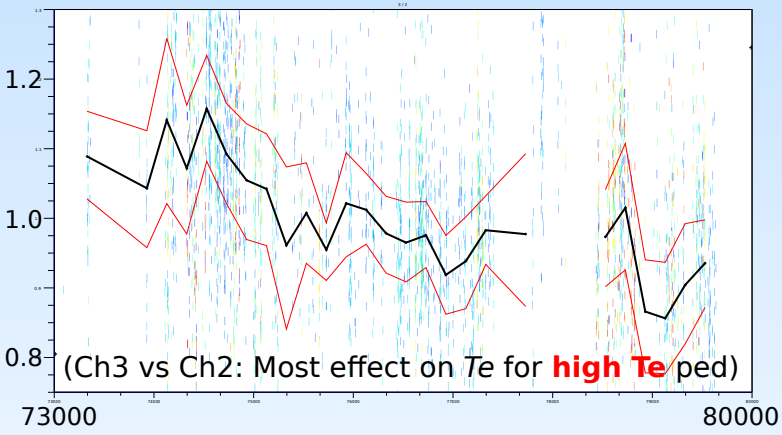

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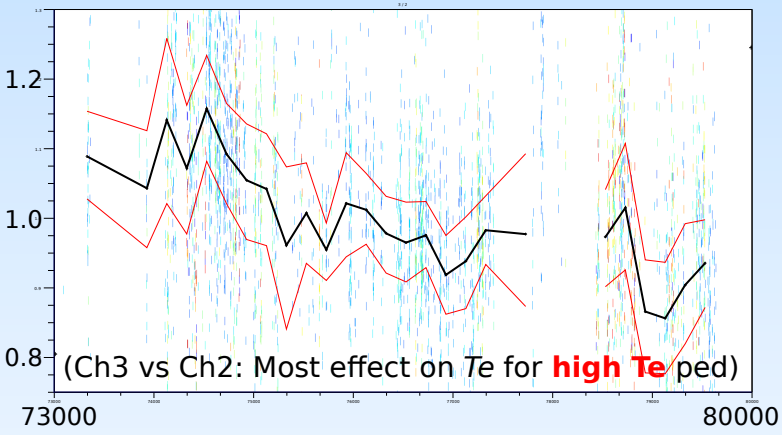

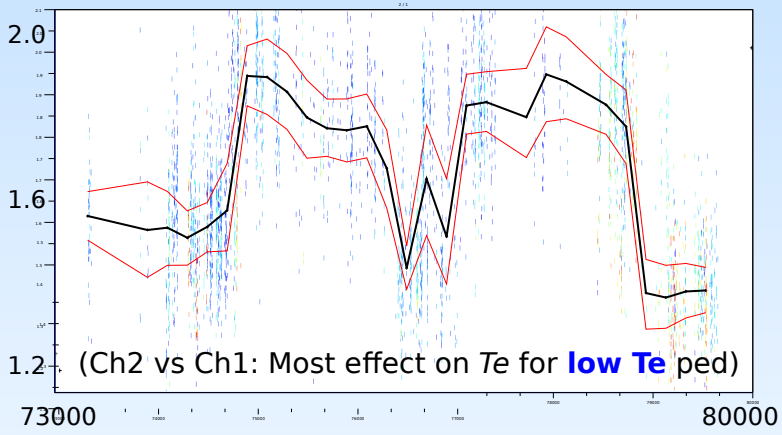

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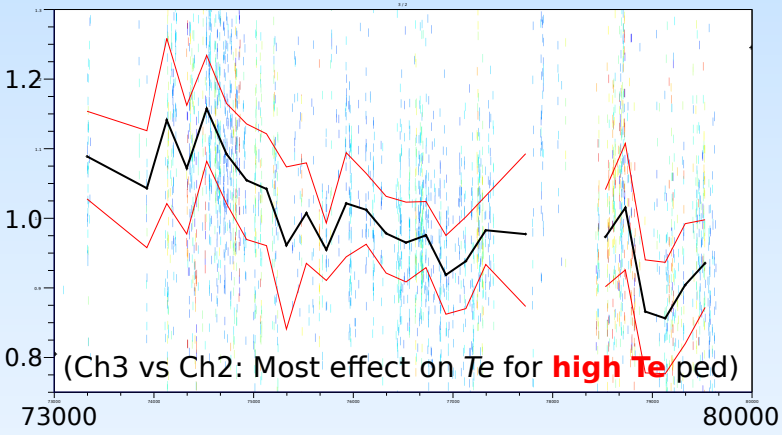

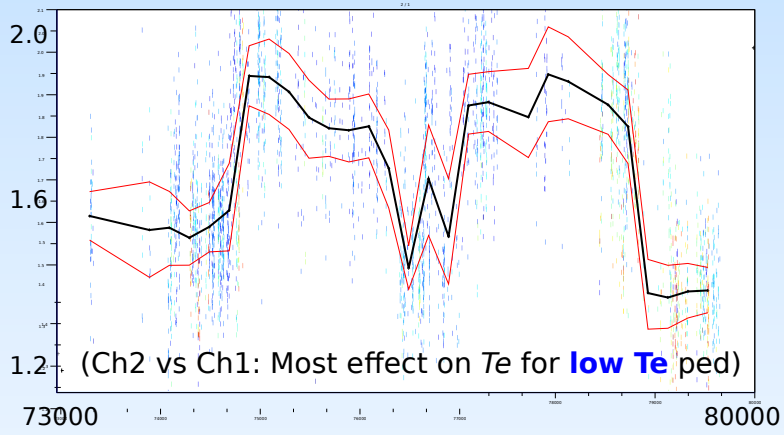

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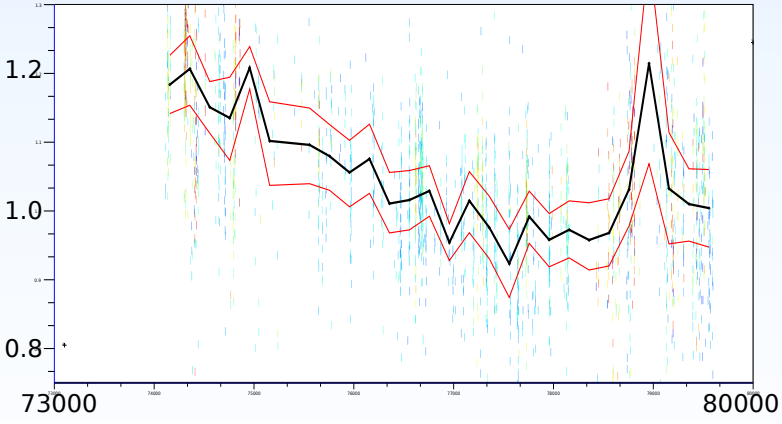

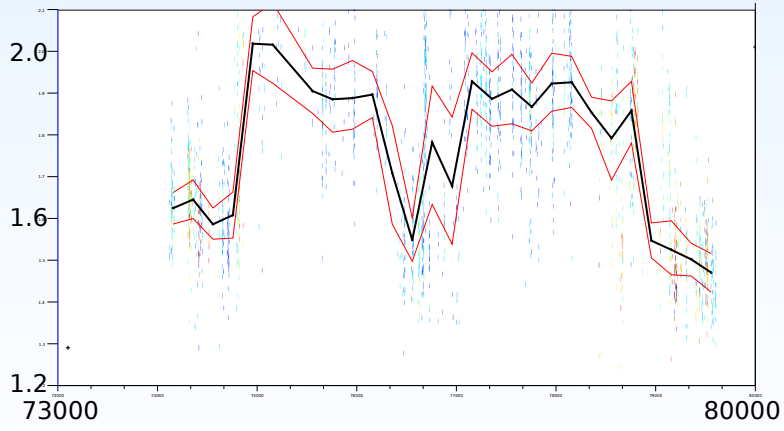

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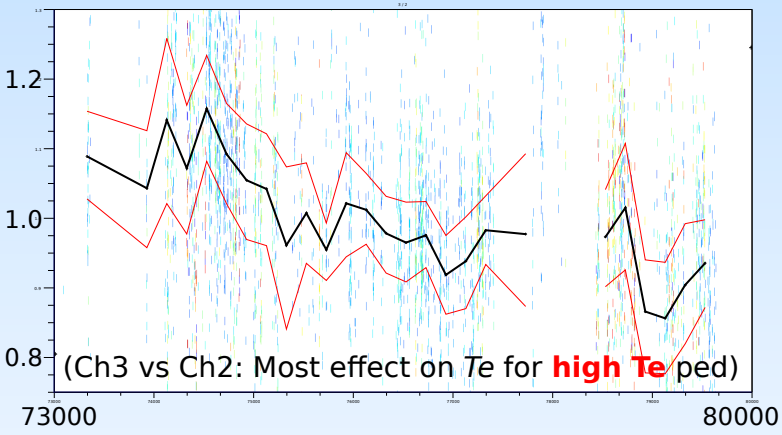

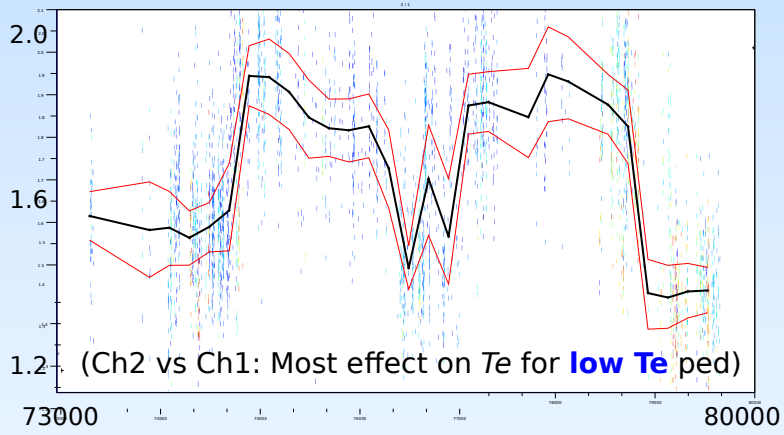

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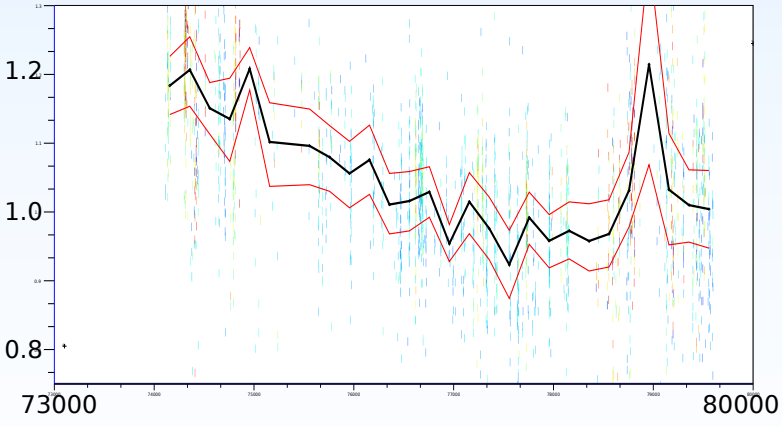

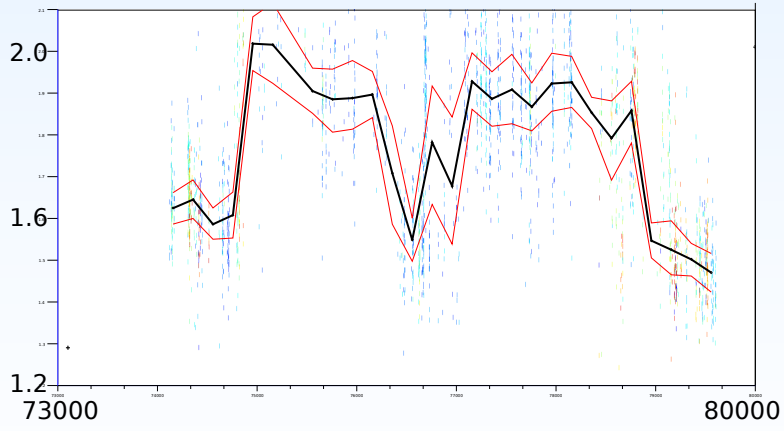

T_e ~ From HRTS

So now, have we constrained the picture enough to do some physics ?
Looked at pedestal widths using Core + Edge LIDAR + Interferometry:
- Works, but usually (pre-ELM) insists T_e pedestal is < 7mm.
- No JET diagnostic can outright disagree, does anyone know for certain?

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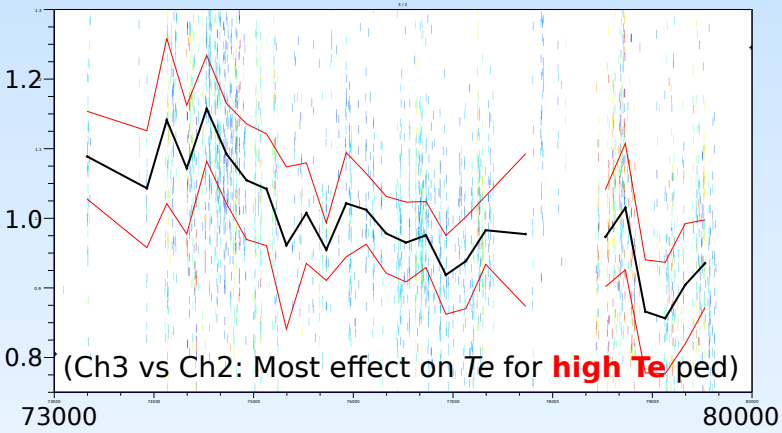

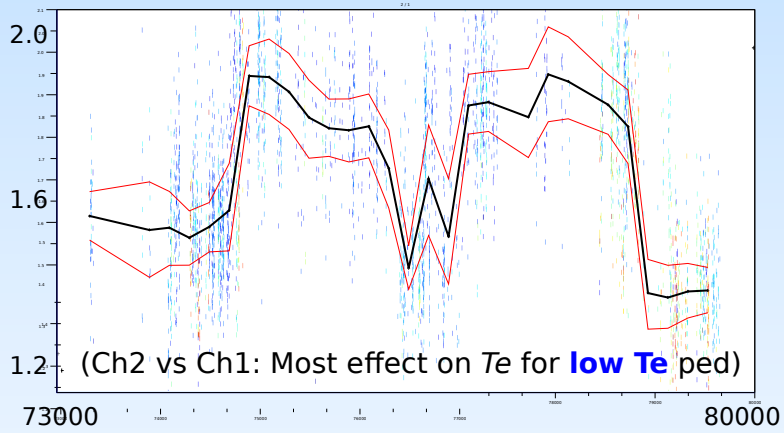

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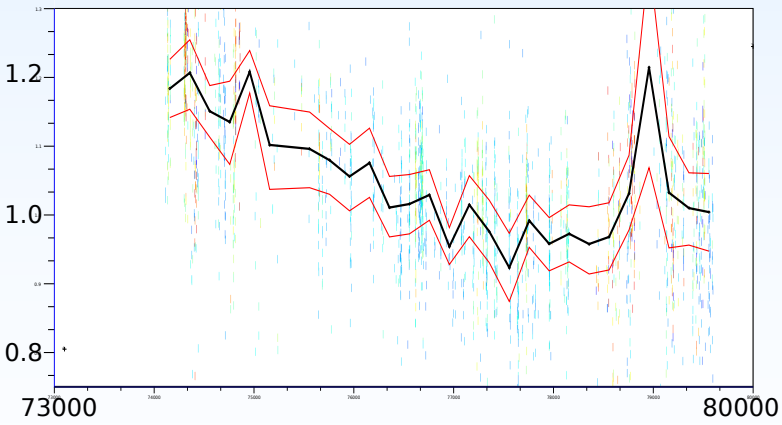

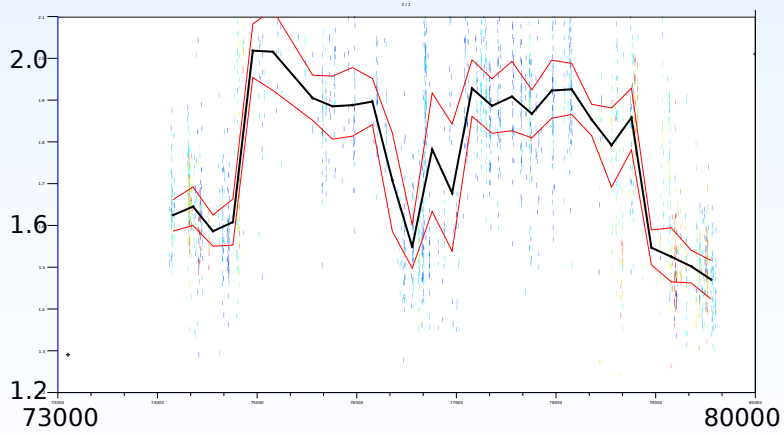

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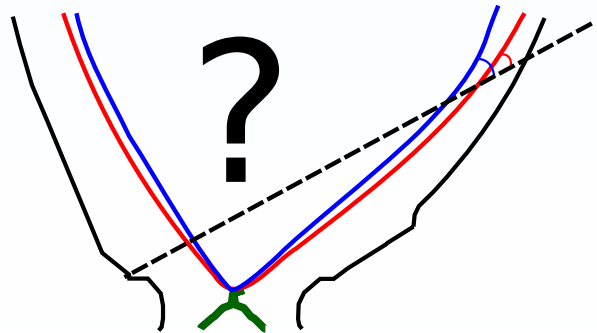
- Only remaining reason might be mapping (since we're fixed to so far).



Equilbrium I

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Will try to explore using Current Tomography with CAR prior and all the diagnositcs (soon)

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NB: It's not immediately clear how restrictive force balance (GS equation) actually is, since it is almost always used with strong prior constraints on *p*' (or *p* - the equilibirum pressure) and *ff*' (or *f* - the poloidal current flux). With weak (almost no) contraints on *p*' and *ff*', degeneracy of solutions is still huge.

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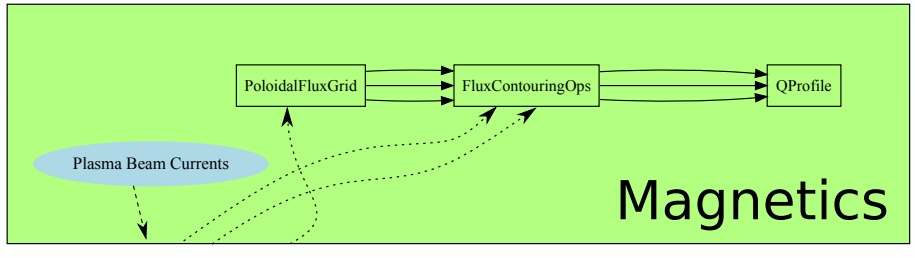

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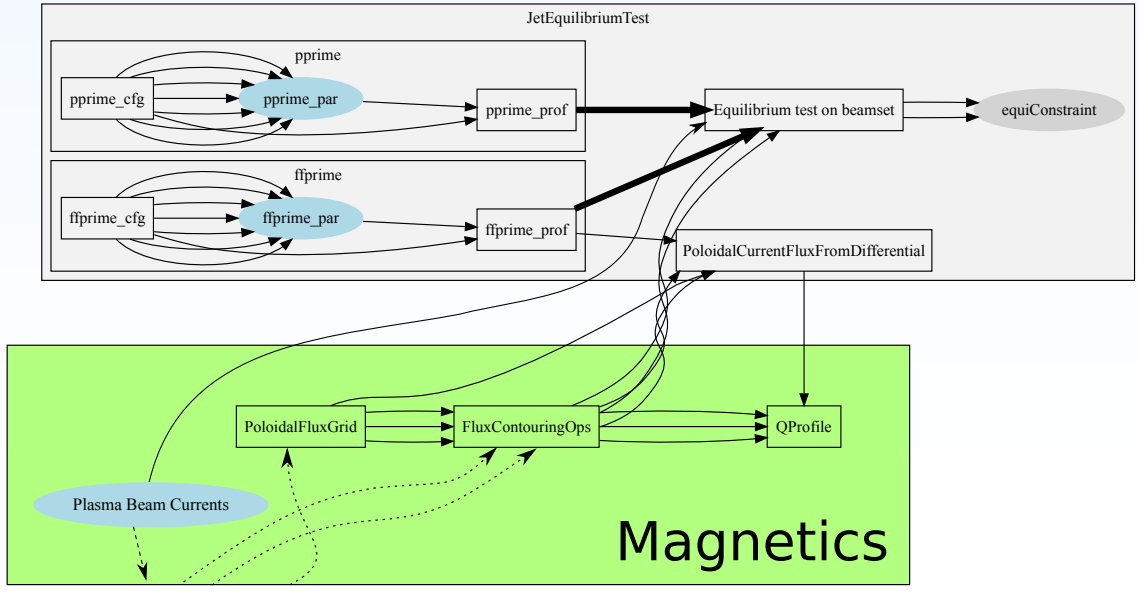

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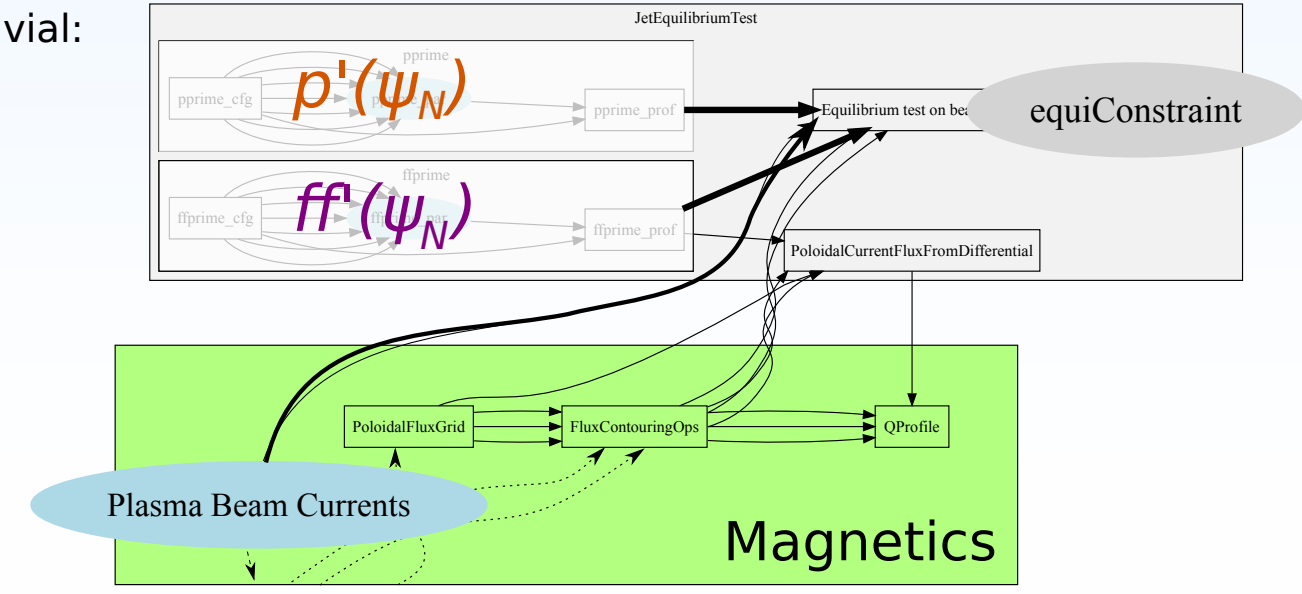

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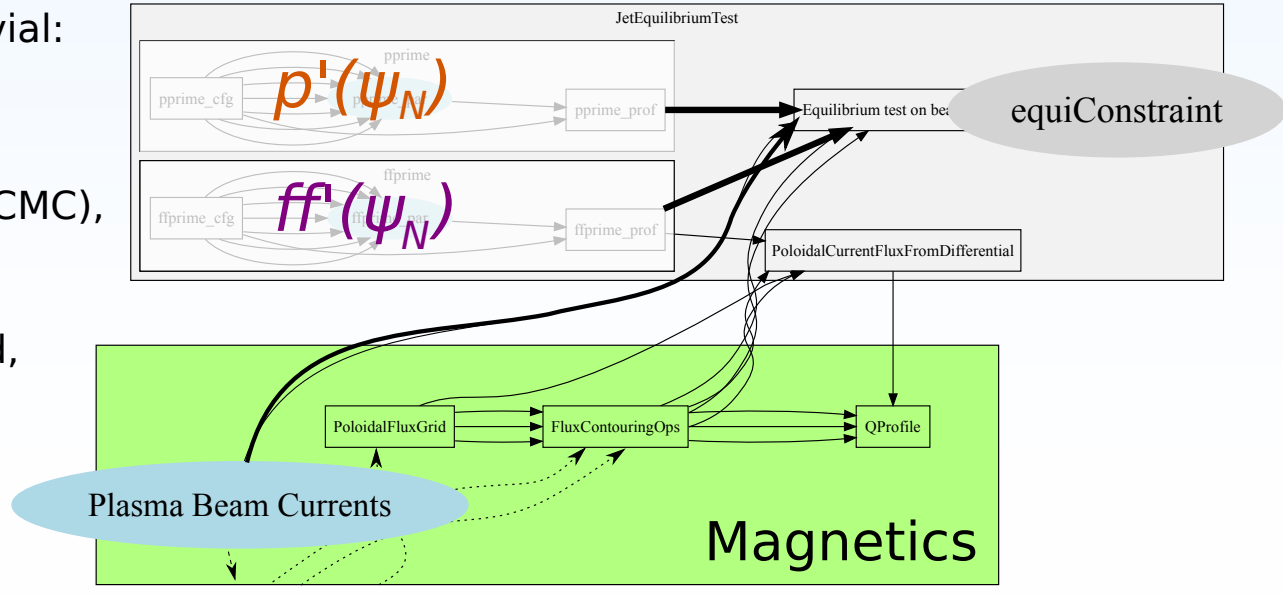
Exploring the PDF is currently beyond the capability of our the present algorithms (MCMC), even for low resolution parametrisations.

Even finding the maximum (best fit) is hard, but can now be done...



Equilbrium II: Maximum Posterior (Magnetics Only)

78601 High ne
H-Mode (pellets)

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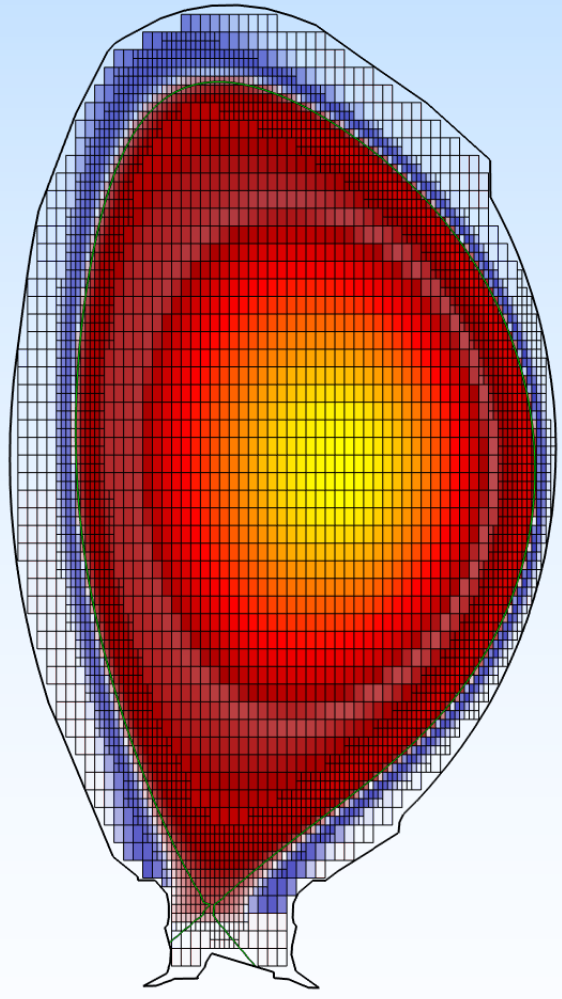

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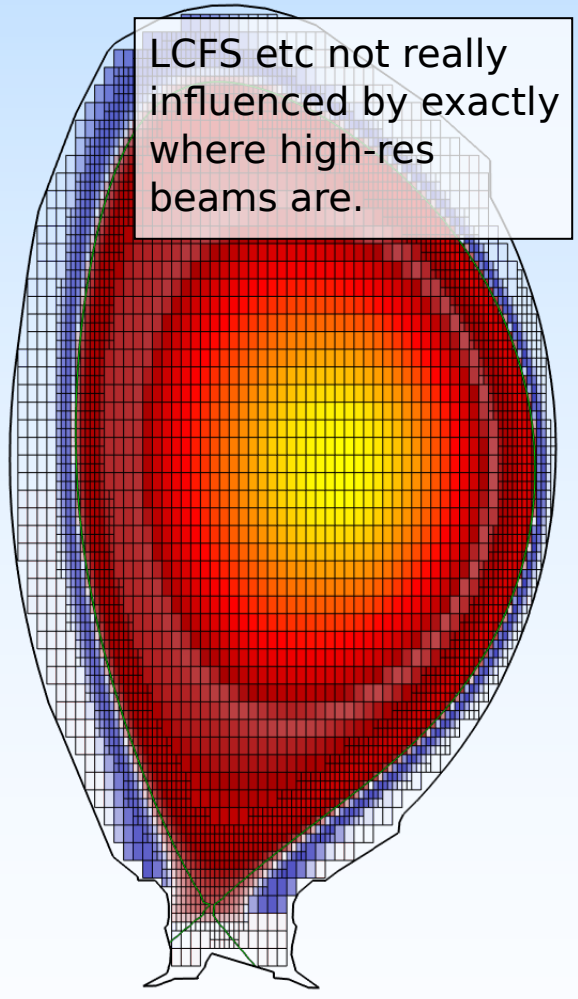

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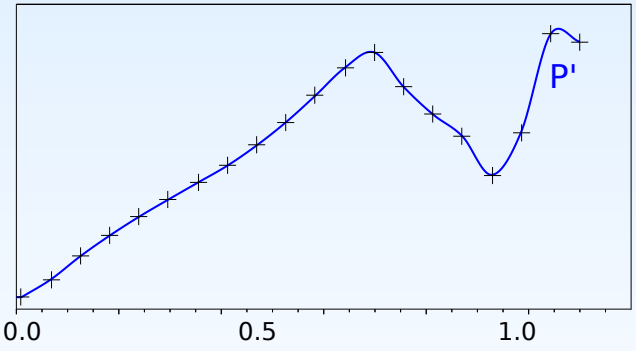

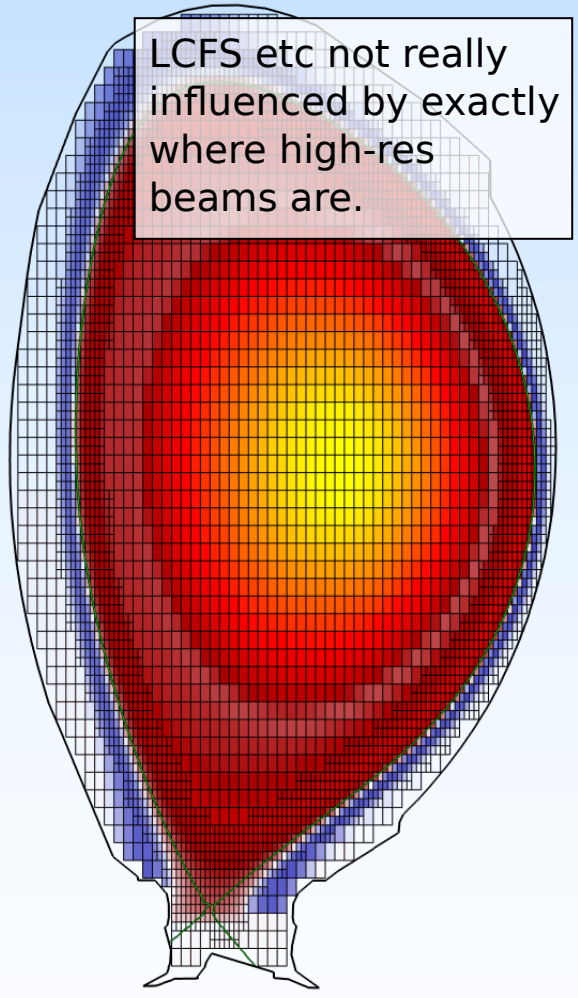

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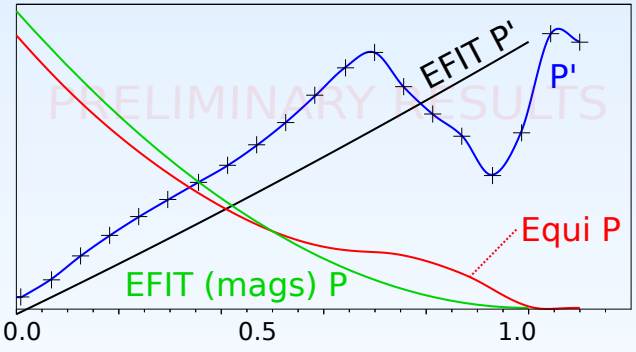

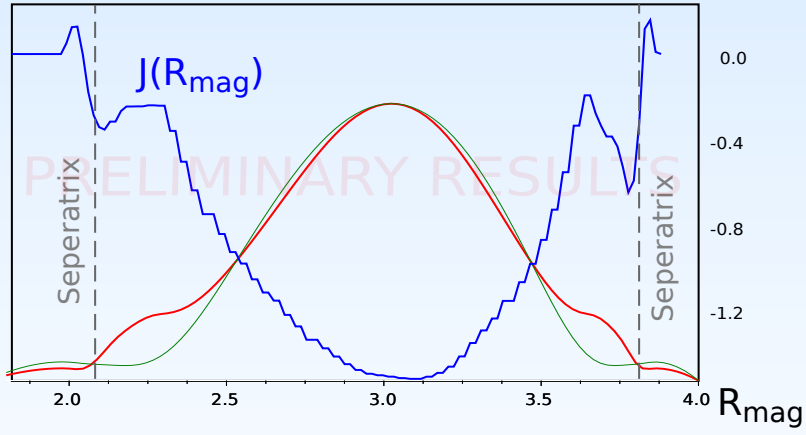

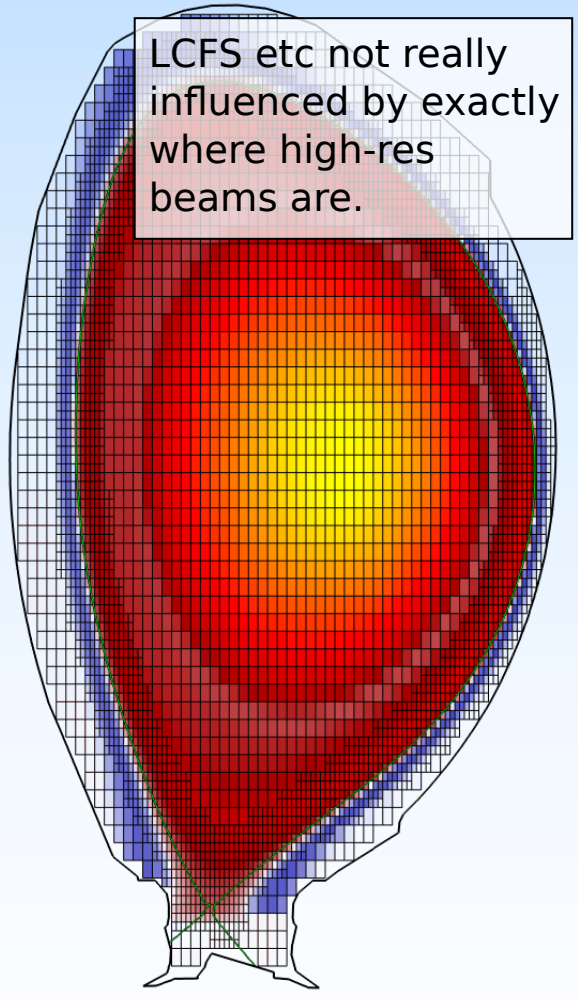

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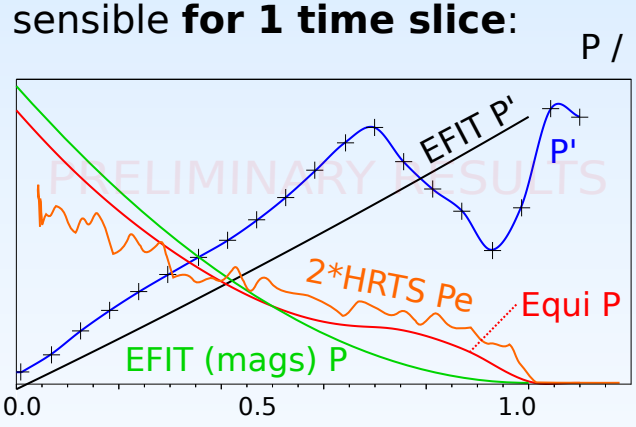

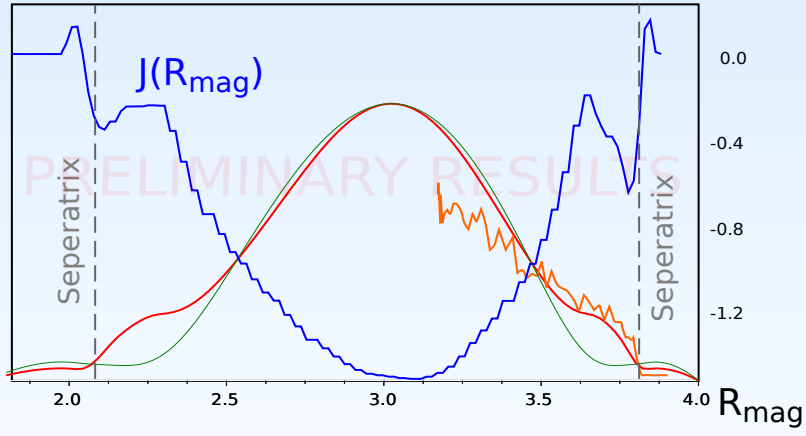

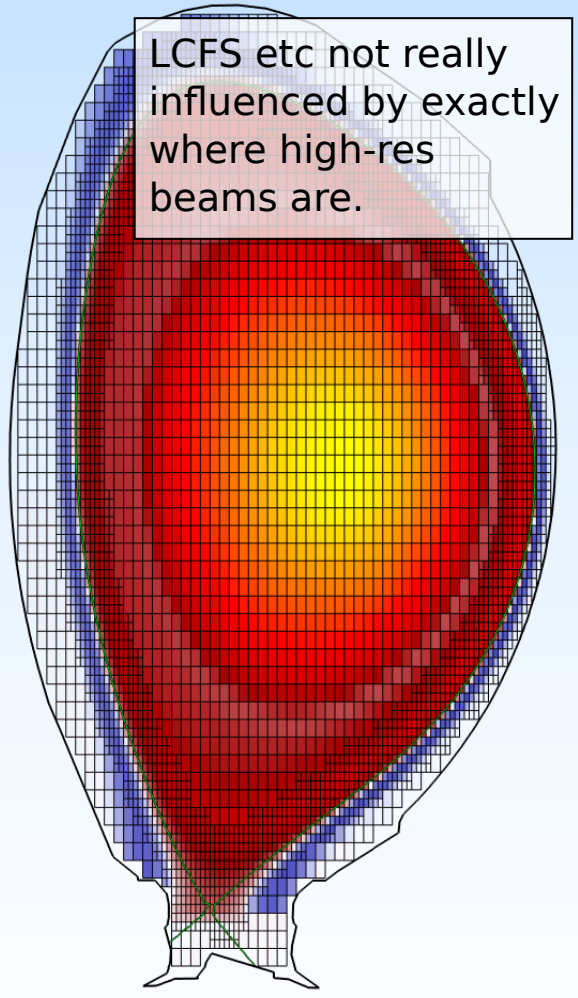

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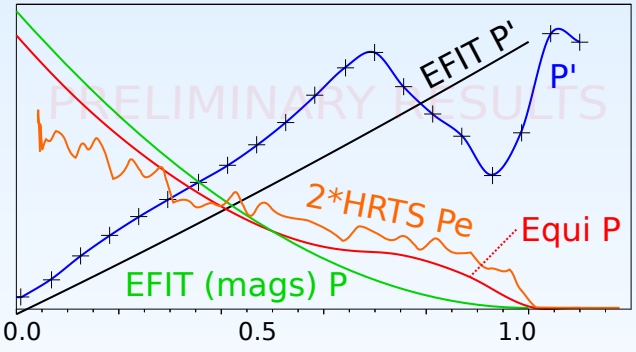

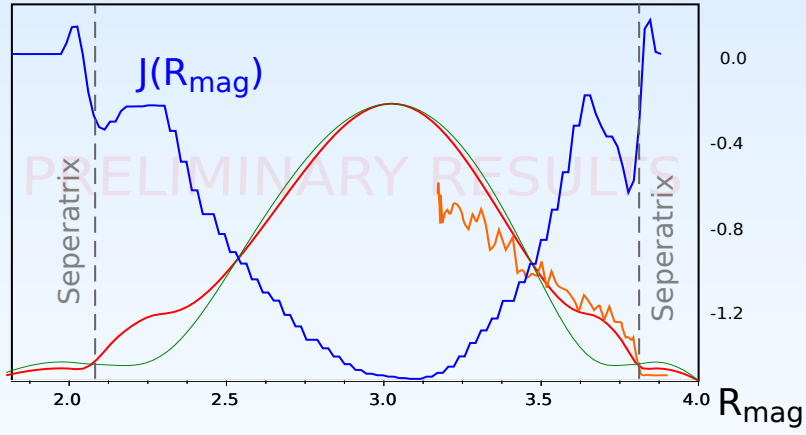

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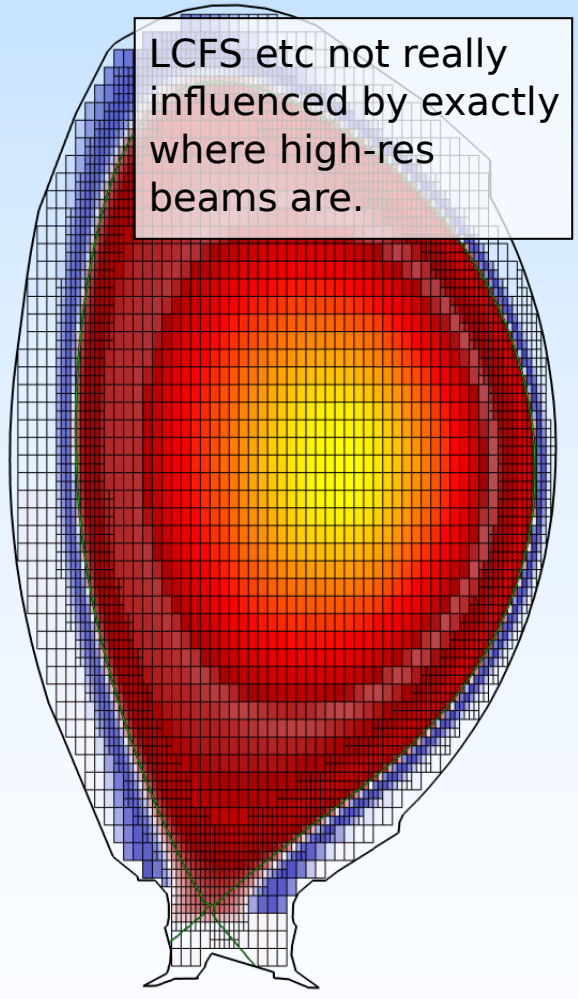

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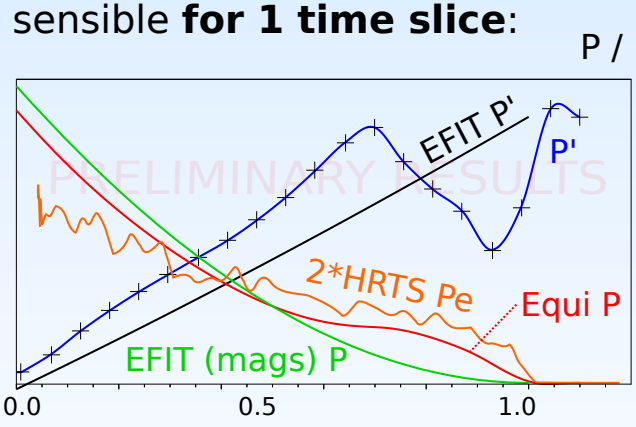

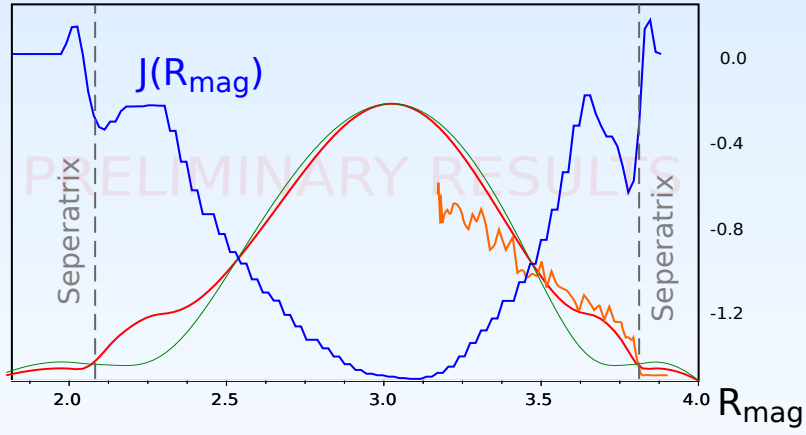

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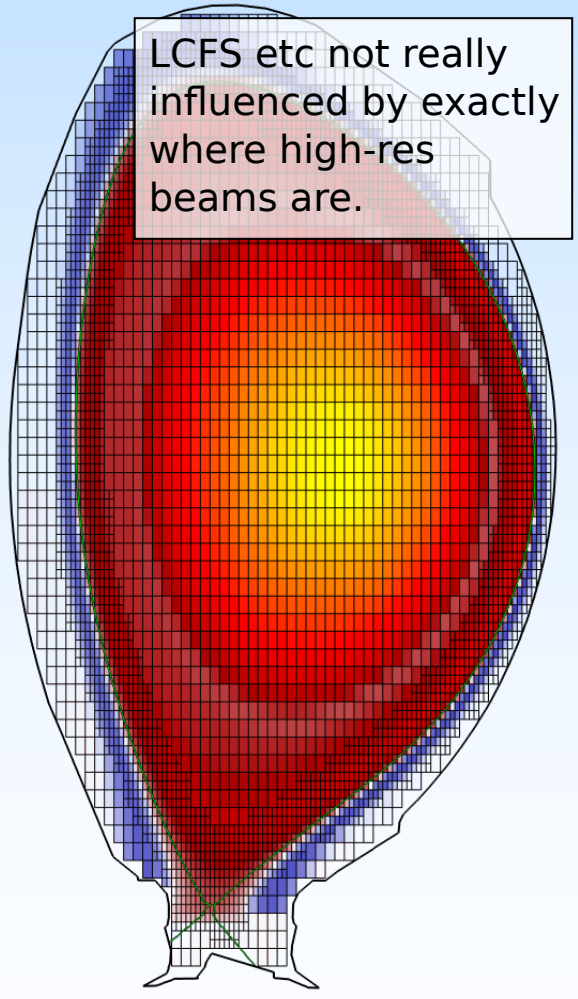

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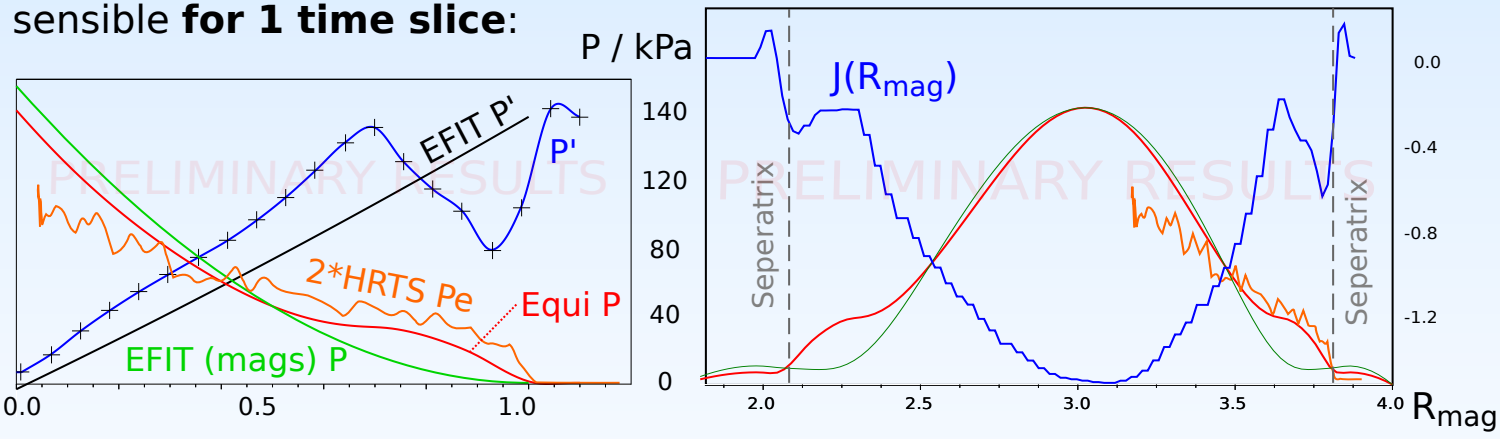

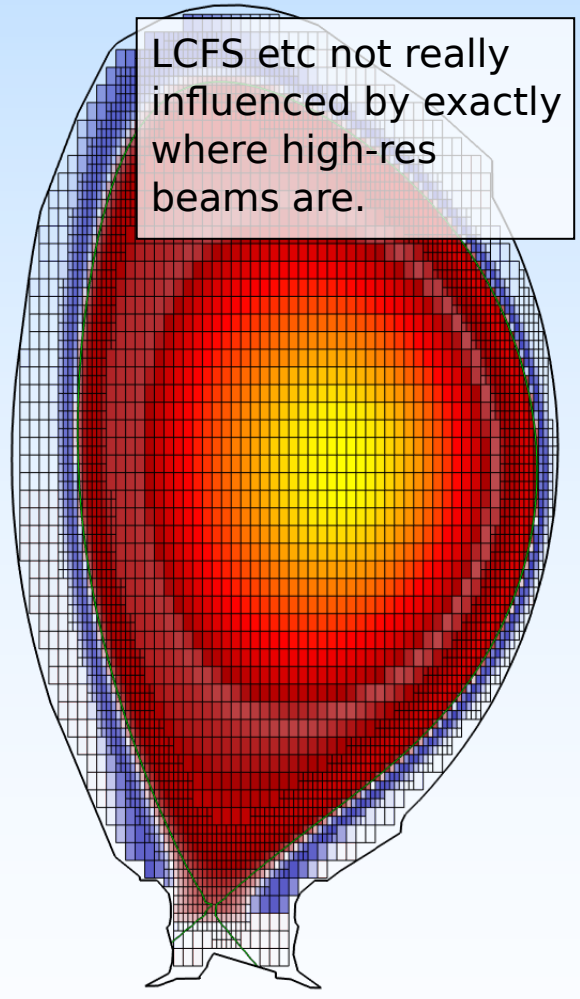

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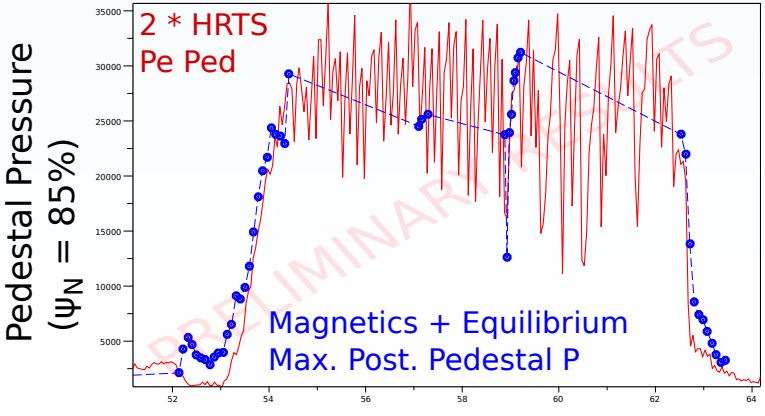

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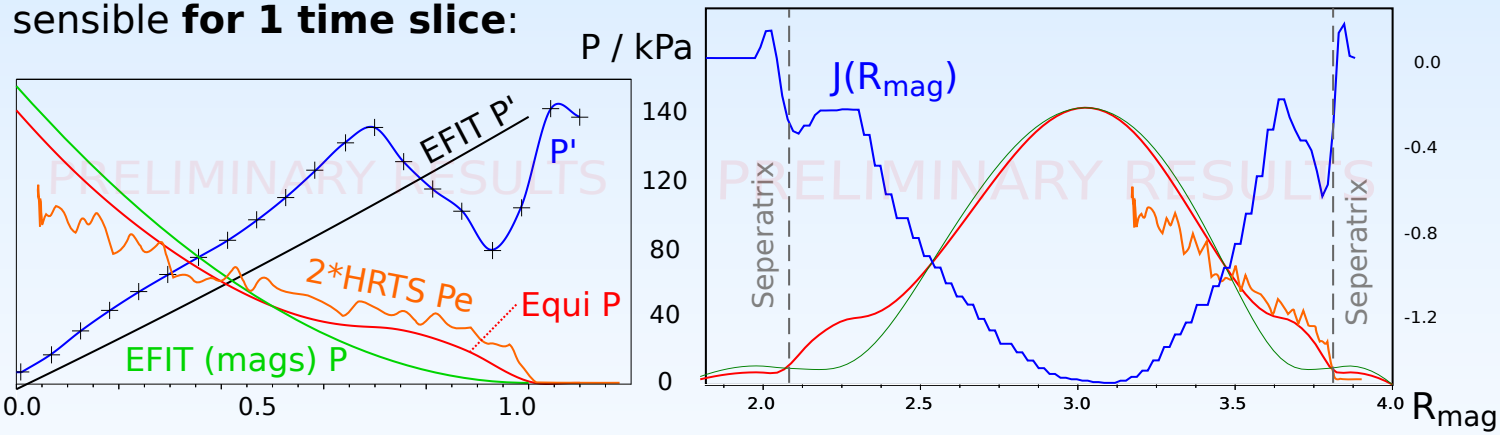

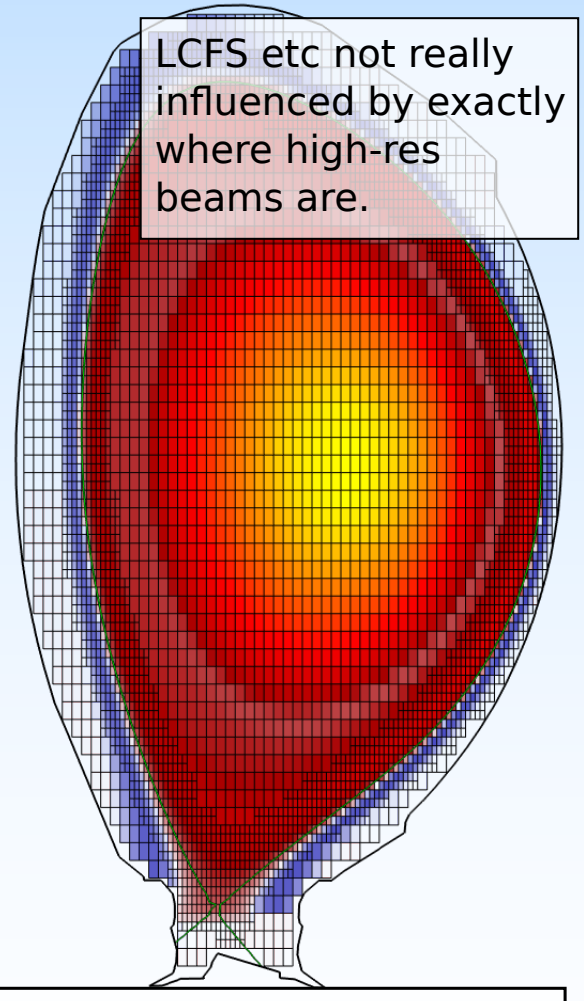

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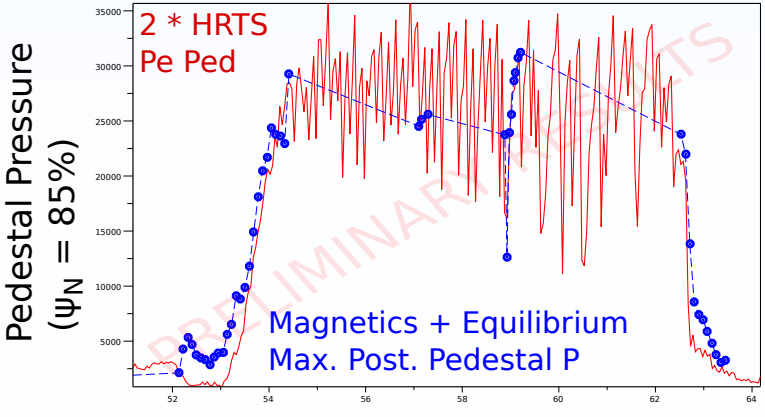

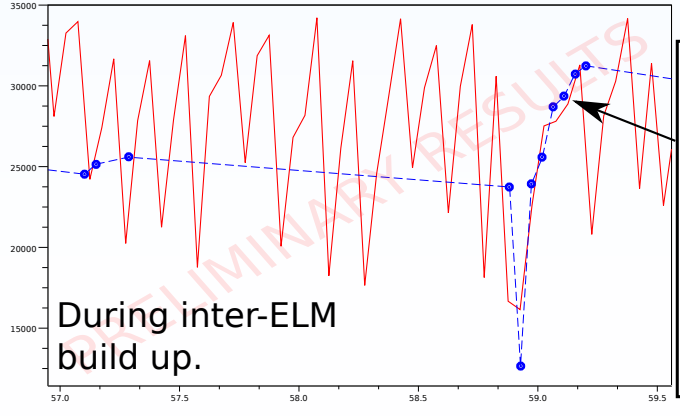

Follows trends AND maintains surprisingly good magnitude.
Suggests there is a quite lot of info in magnetics!
What is P(Jedge | Dmags)?
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